Senior Design Report
for
ECE 477 – Spring 2012

submitted by

Prof. David G. Meyer

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PURDUE UNIVERSITY

School of Electrical & Computer Engineering

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Course Description

Digital Systems Senior Design Project (ECE 477) is a structured approach to the development and integration of embedded microcontroller hardware and software that provides senior-level students with significant design experience applying microcontrollers to a wide range of embedded systems (e.g., instrumentation, process control, telecommunications, intelligent devices, etc.). The primary objective is to provide practical experience developing integrated hardware and software for embedded microcontroller systems in an environment that models one which students will most likely encounter in industry.

One of the unique features of this course is that each team gets to choose their own specific project (subject to some general constraints) and define specific success criteria germane to that project. In general, this approach to senior design provides students with a sense of project ownership as well as heightened motivation to achieve functionality.

Course web site: https://engineering.purdue.edu/ece477

Course Staff

Name	*Title / Role*	*E-mail Address*
Prof. David Meyer	Faculty / Project Advisor	meyer@purdue.edu
Dr. Mark Johnson	Faculty / Project Advisor	mcjohnso@purdue.edu
George Hadley	Teaching Assistant / Project Consultant	ghadley@purdue.edu
George Toh	Teaching Assistant / Project Consultant	ytoh@purdue.edu
Jacob Pfister	Teaching Assistant / Project Consultant	jpfister@purdue.edu
Charles Barnett	Lab Technical Support	barnettc@purdue.edu

Lecture Schedule / Course Calendar

ECE 477 – *Digital Systems Senior Design Project* – Spring 2012

COURSE CALENDAR

Monday	Tuesday	Wednesday	Thursday	Friday
Jan 9	Jan 10 Course Introduction 1:30-2:20 EE 117	Jan 11 Mods 1 & 2 Digital Design 11:30-1:20 EE 117/226	Jan 12 Module 3 uC survey 1:30-2:20 EE 117	Jan 13 Preliminary Proposal Due
Jan 16 MLK Day	Jan 17 Module 4 Emb Sys I/F 1:30-2:20 EE 117	Jan 18 Module 5 PCB Design 11:30-1:20 EE 117/226	Jan 19 Module 6 Pow Sup Des 1:30-2:20 EE 117	Jan 20 Final Proposal Due
Jan 23	Jan 24 Module 6 Pow Sup Des 1:30-2:20 EE 117	Jan 25 **TCSP** PSSCs 11:30-1:20 EE 117/226	Jan 26 Module 7 Pkg & Cnstr 1:30-2:20 EE 117	Jan 27 PCB Tutorial Exercise Due
Jan 30	Jan 31 Module 8 Pass Cmp Sel 1:30-2:20 EE 117	Feb 1 **TCSP** Constr Anal 11:30-1:20 EE 117/226	Feb 2 Module 8 Pass Cmp Sel 1:30-2:20 EE 117	Feb 3 Design Constraint Analysis Due
Feb 6	Feb 7 Module 9 Doc Stnds 1:30-2:20 EE 117	Feb 8 **TCSP** Packaging 11:30-1:20 EE 117/226	Feb 9 Module 10 Software Des 1:30-2:20 EE 117	Feb 10 Packaging Design Due
Feb 13 Lab Notebook Evaluation	Feb 14 Module 11 Assem/Solder 1:30-2:20 EE 117	Feb 15 **TCSP** Schematic 11:30-1:20 EE 117/226	Feb 16 Module 12 Debugging 1:30-2:20 EE 117	Feb 17 Preliminary Schematic and Design Narrative Due
Feb 20	Feb 21 Prep for Design Revs 1:30-2:20 EE 117	Feb 22 **TCSP** PCB Design 11:30-1:20 EE 117/226	Feb 23 Progress Briefings 1:30-2:20 EE 061/063	Feb 24 Preliminary PCB Layout and Design Narrative Due
Feb 27	Feb 28 **Formal Design Reviews MSEE 239**	Feb 29 **Formal Design Reviews MSEE 239**	Mar 1 **Formal Design Reviews MSEE 239**	Mar 2

Monday	Tuesday	Wednesday	Thursday	Friday
Mar 5	Mar 6 Notebook Remediation 1:30-2:20 EE 117	Mar 7 Progress Briefings 11:30-1:20 EE 061/063	Mar 8	Mar 9 **Proof-of-Parts** **Final Schematic** **Final PCB Due**
Mar 12 Spring Break	Mar 13 Spring Break	Mar 14 Spring Break	Mar 15 Spring Break	Mar 16 Spring Break
Mar 19 Midterm Peer Evaluation Due	Mar 20 Module 13 Patent Liab 1:30-2:20 EE 117	Mar 21 **TCSP** Software 11:30-1:20 EE 117/226	Mar 22 Module 13 Patent Liab 1:30-2:20 EE 117	Mar 23 Software Design Narrative Due
Mar 26 Lab Notebook Evaluation	Mar 27 Module 14 Rel/Safe Anal 1:30-2:20 EE 117	Mar 28 **TCSP** Patent Liability 11:30-1:20 EE 117/226	Mar 29 Module 14 Rel/Safe Anal 1:30-2:20 EE 117	Mar 30 Patent Liability Analysis Due
Apr 2	Apr 3 Module 15 Eth/Env Imp 1:30-2:20 EE 117	Apr 4 **TCSP** Reli & Safety 11:30-1:20 EE 117/226	Apr 5 Module 15 Eth/Env Imp 1:30-2:20 EE 117	Apr 6 Reliability and Safety Analysis Due
Apr 9	Apr 10 Prep for Pres Exam Review 1:30-2:20 EE 117	Apr 11 **TCSP** Eth/Env Imp 11:30-1:20 EE 117/226	Apr 12	Apr 13 Ethical and Enviro Impact Analysis Due
Apr 16	Apr 17	Apr 18 **Dsng & Prof Atrb Accountability Exercise** 11:30-1:20 EE 117	Apr 19	Apr 20 User Manual Due
Apr 23	Apr 24 Progress Briefings 1:30-2:20 EE 061/063	Apr 25 **TCSP** **PSSC Demos** 11:30-1:20 EE 117	Apr 26	Apr 27 ECE 270/362 Bonus Credit Presentations (by invitation)

Formal Design Reviews for each team will be scheduled on 2/28, 2/29, and 3/1 Final Presentation Session will be on May 2, 8:00 AM – 12:00 PM in EE 170

Final Lab Notebook Evaluation, Confidential Peer Review, Final Report, Poster, and Senior Design Report submitted on-line by **5:00 PM Apr 30**

Design Project Specifications / Requirements

Work on the design project is to be completed in teams of four students. The design project topic is flexible, and each group is encouraged to pick a product that uses the strengths and interest areas of their group members. The design must have the following components:

- **Microcontroller:** To help make the project tractable, recommended microcontroller choices include Freescale, PIC, and Atmel variants. Development tools are readily available in lab to support these devices. Further, the devices themselves are relatively low cost and readily available. Optionally, auxiliary processing can be accomplished using a “motherboard”. Examples of these directly supported are Intel Atom and ARM-based platforms.
- **Interface to Something:** Your embedded system must interface to some other device or devices. It could be a computer, or it could be some embedded device such as a Palm Pilot, telephone line, TV, etc. Some interface standards that could be used are: serial to a computer, parallel to a computer, Universal Serial Bus (USB), Firewire, Ethernet, Infrared (IR), Radio Frequency (RF), etc. This requirement has a large amount of freedom. To help with some of the more complex interfaces such as Ethernet, USB, or Firewire there are dedicated chips which encapsulate the lowest layers of the interface. This makes using these interfaces easier to handle but not necessarily trivial. Be sure to investigate the interface(s) you wish to utilize and make a reasonable choice. (NOTE: *Interfaces involving A.C. line current require special permission – see the instructor for details.*)
- **Custom printed circuit board:** Through the process of the design, each group will be required to draw a detailed schematic. From the schematic, a two-layer printed circuit board will be created. Board etching will be processed by the ECE Department (the first one is “free”, but any subsequent iterations are the team’s responsibility). The team is then responsible for populating the board (solder the parts on the board), and for completing the final stages of debugging and testing on their custom board.
- **Be of personal interest to at least two team members:** It is very difficult to devote the time and energy required to successfully complete a major design project in which you and/or your team members have no personal interest. There are *lots* of possibilities, ranging from toys and games to “useful and socially redeeming” household items, like audio signal processors and security systems.
- **Be tractable:** You should have a “basic idea” of how to implement your project, and the relative hardware/software complexity involved. For example, you should not design an “internet appliance” if you have no idea how TCP/IP works. Also, plan to use parts that are reasonably priced, have reasonable footprints, and are *readily available*. Be cognizant of the prototyping limitations associated with surface mount components.
- **Be neatly packaged:** The finished project should be packaged in a reasonably neat, physical sound, environmentally safe fashion. Complete specification and CAD layout of the packaging represents one of the project design components.
- **Not involve a significant amount of “physical” construction:** The primary objective of the project is to learn more about *digital system* design, not mechanical engineering! Therefore, most of the design work for this project should involve digital hardware and software.

Project Proposal: Each group should submit a proposal outlining their design project idea. This proposal should not be wordy or lengthy. It should include your design objectives, design/functionality overview, and project success criteria. The five success criteria common to all projects include the following:

- Create a bill of materials and order/sample all parts needed for the design
- Develop a complete, accurate, readable schematic of the design
- Complete a layout and etch a printed circuit board
- Populate and debug the design on a custom printed circuit board
- Package the finished product and demonstrate its functionality

In addition to the success criteria listed above, a set of **five significant** *project-specific* success criteria should be specified. The degree to which these success criteria are achieved will constitute one component of your team's grade.

Forms for the preliminary and final versions of your team's project proposal are available on the course web site. Use these skeleton files to create your own proposal. Note that the proposal should also include assignment of each team member to one of the design components as well as to one of the professional components of the project.

Group Account and Team Webpage: Each team will be assigned an ECN group account to use as a repository for all their project documentation and for hosting a password-protected team web page. The team web page should contain datasheets for all components utilized, the schematic, board layout, software listings, interim reports, presentation slides, etc. It should also contain the individual lab notebooks for each team member as well as the progress reports (prepared in advance of the weekly progress briefings) for each team member. At the end of the semester, each team website will be archived on the course website.

Design Review: Part way through the design process, there will be a formal design review. This is a critical part of the design process. In industry, this phase of the design process can often make or break your project. A good design review is one where a design is actively discussed and engineers present concur with the current or amended design. The design review is in some cases the last chance to catch errors before the design is frozen, boards are etched, and hardware is purchased. *A friend is not someone who rubber-stamps a design, but rather one who actively challenges the design to confirm the design is correct.*

Approach the design review from a top-down, bottom-up perspective. First, present a block diagram of your design and explain the functional units. Then drop to the bottom level and explain your design at a schematic level. Be prepared to justify every piece of the design; a perfectly valid answer, however, is applying the recommended circuit from an application note. If you do use a circuit from an application note, have the documentation on hand and be able to produce it. *Your grade for the design review will not be based on the number of errors identified in your design.* The best engineers make mistakes, and the purpose of the design review is to *catch them* rather than spend *hours of debugging later* to find them. The design review will be graded primarily on how well the group understands their design and the professionalism with which they present it.

To facilitate the design review process, the class will be split into subgroups that will meet at individually scheduled times. Both the presenters and the assigned reviewers will be evaluated.

Design Project Milestones

Each group is responsible for setting and adhering to their own schedule; however, there are several important milestones, as listed in the table below. Always "expect the unexpected" and allow for some buffer in your schedule. *Budget your time.* With proper budgeting, senior design can be a very rewarding and pleasant experience.

See course schedule for homework due dates.

Week	*Milestone*
1	Formulate project ideas Preliminary project proposal due
2	Research parts, create initial block diagram and initial BOM Final project proposal due
3	Order/sample parts, review/learn OrCad *Capture* and *Layout*
4	Create detailed BOM (including resistors, capacitors, etc.)
5	Draw preliminary schematic Prototype interface circuits
6	Finalize schematic Begin PCB layout Begin prototyping software with EVB/prototype
7	Finalize PCB layout for Design Review Continue software development Prepare for Design Review
8	Continue software development **DESIGN REVIEWS**
9	Incorporate changes/comments from Design Review **Proof-of-Parts due** **Final schematic due** **PCB file submission due**
10	Continue software development on EVB
11	PCBs arrive - begin populating/testing
11-15	Test PCB section-by-section as parts are added, porting software as you go - *add functions one-by-one so you know what it was that "broke" your code or your board when things stop working*
16	**PSSC Demos** Prepare for Final Presentation
Finals	**FINAL PRESENTATIONS**

Course Outcomes and Assessment Procedures

In order to successfully fulfill the course requirements and receive a passing grade, each student is expected to demonstrate the following outcomes:

(i) an ability to apply knowledge obtained in earlier coursework and to obtain new knowledge necessary to design and test a microcontroller-based digital system
(ii) an understanding of the engineering design process
(iii) an ability to function on a multidisciplinary team
(iv) an awareness of professional and ethical responsibility
(v) an ability to communicate effectively, in both oral and written form

The following instruments will be used to assess the extent to which these outcomes are demonstrated (the forms used to "score" each item are available on the course web site):

Outcome	*Evaluation Instruments Used*
(i)	Design Component Homework
(ii)	Individual Lab Notebooks
(iii)	Success Criteria Satisfaction (general *and* project-specific)
(iv)	Professional Component Homework
(v)	Formal Design Review, Final Presentation, and Final Report

Students must demonstrate basic competency in ***all*** the course outcomes, listed above, in order to receive a passing grade. Demonstration of Outcome (i) will be based on the satisfaction of the design component homework, for which a minimum score of **60%** will be required to establish basic competency. Demonstration of Outcome (ii) will be based on the individual lab notebook, for which a minimum score of **60%** will be required to establish basic competency. Demonstration of Outcome (iii) will be based on satisfaction of the **100%** of the general success criteria and a minimum of **60%** (3 out of 5) of the project-specific success criteria (PSSC). Note: If a "motherboard" is used, at least 2 of the 3 "passing PSSC" must involve functions implemented on the custom PCB. Demonstration of Outcome (iv) will be based on the professional component homework, for which a minimum score of **60%** will be required to establish basic competency. Demonstration of Outcome (v) will be based on the Design Review, the Final Presentation, and the Final Report. A minimum score of **60%** on the Design Review and a minimum score of **60%** on the Final Report and a minimum score of **60%** on the Final Presentation will be required to establish basic competency.

Since *senior design* is essentially a "mastery" style course, students who fail to satisfy all outcomes but who are otherwise passing (based on their NWP) will be given a grade of "I" (incomplete). The grade of "I" may subsequently be improved upon successful satisfaction of all outcome deficiencies. If outcome deficiencies are not satisfied by the prescribed deadline, the grade of "I" will revert to a grade of "F".

Course Grade Determination

Homework: Several "homeworks" will be assigned related to key stages of the design project. Some of the assignments will be completed as a team (0, 1, 7, 13, 15, 16, 17), three will be completed individually (2, 8, 14), and the remainder will be completed by a selected team member (one from the set {4, 5, 6, 9} and one from the set {3, 10, 11, 12}).

1. Team Building and Project Idea
2. Project Proposal
3. PCB Tutorial
4. Design Constraint Analysis and Component Selection Rationale
5. Packaging Specifications and Design
6. Hardware Design Narrative/Preliminary Schematic
7. PCB Design Narrative/Preliminary PCB Layout
8. PCB Submission, Final Schematic, and Parts Acquisition/Fit
9. Peer Review – Midterm
10. Software Design Narrative, and Documentation
11. Patent Liability Analysis
12. Reliability and Safety Analysis
13. Ethical/Environmental Impact Analysis
14. User Manual

These assignments are due on the prescribed due dates (typically Fridays) at NOON. The following penalties will be applied for work submitted late:

- 10% if submitted no more than 24 hours late
- 20% if submitted no more than 48 hours late
- 30% if submitted no more than 72 hours late
- 100% if submitted any later

15. Peer Review – Final,
16. Senior Design Report
17. Final Report
18. Poster

These assignments are all due on Monday, 4/30, at 5:00 PM. Late penalties will be assessed per above late policy. However, these materials will NOT be accepted at all after 5:00 PM on Thursday, 5/3.

Grade Determination: Your course grade will be based on team effort (40%) and your individual contributions (60%), as follows:

TEAM COMPONENTS (40% of total) distribution of team component:		**INDIVIDUAL COMPONENTS (60% of tot.) distribution of individual component**	
Project Success Criteria Satisfaction*	20.0%	Laboratory Design Notebook*	20.0%
Design Review*	15.0%	Design Component Report*	15.0%
Final Presentation*	15.0%	Professional Component Report*	15.0%
Final Report*	15.0%	Significance of Individual Contribution	15.0%
System Integration and Packaging	10.0%	Design & Professional Attribute Exam	10.0%
User Manual	7.5%	Peer Reviews (Confidential, DR, and Video)	10.0%
Senior Design Report	7.5%	TCSP Peer Reviews (9)	5.0%
Proof-of-Parts and PCB Submission	5.0%	PCB Tutorial	5.0%
Poster	5.0%	Class Participation - Clicker Exercises	2.5%
** items directly related to outcome assessment*		Class Participation - Team Exercises	2.5%

Your **R**aw **W**eighted **P**ercentage (RWP) will be calculated based on the weights, above, and then "curved" (i.e., mean-shifted) with respect to the upper percentile of the class to obtain a **N**ormalized **W**eighted **P**ercentage (NWP). Equal-width cutoffs will then be applied based on the **W**indowed **S**tandard **D**eviation (WSD) of the raw class scores; the minimum **C**utoff **W**idth **F**actor (CWF) used will be 10 (i.e., the nominal cutoffs for A-B-C-D will be 90-80-70-60, respectively). Before final grades are assigned, the course instructor will carefully examine all "borderline" cases (i.e., NWP within 0.5% of cutoff). Once grades are assigned, they are **FINAL** and WILL NOT be changed. Note that **all** course outcomes must be demonstrated in order to receive a passing grade for the course.

Course Assessment Report

Course: ECE 477 **Submitted by:** D. G . Meyer
Term: Spring 2012 **Course PIC:** D. G. Meyer

1. **Did all students who received a passing grade demonstrate achievement of each course outcome? If not, why not and what actions do you recommend to remedy this problem in future offerings of this course? (Attach additional sheets as necessary)**

   Yes

   a. **How many course outcomes are there for this course?** 5

   b. **On a scale from 0 – 4 (0=not at all, 1=marginal, 2=adequate, 3=good, 4=very good), please rate, on average, the overall degree to which the students in this course achieved each of the course outcomes.**

Outcome 1	4	Outcome 5	4	Outcome 9		Outcome 13	
Outcome 2	4	Outcome 6		Outcome 10		Outcome 14	
Outcome 3	4	Outcome 7		Outcome 11		Outcome 15	
Outcome 4	4	Outcome 8		Outcome 12		Outcome 16	

2. **Are the course outcomes appropriate? If not, explain. (Attach additional sheets as necessary)**

   Yes – they are the standard “senior design” outcomes

3. **Are the students adequately prepared for this course and are the course prerequisites and co-requisites appropriate? If not, explain. (Attach additional sheets as necessary)**

   Yes

4. **Do you have any suggestions for improving this course? If so, explain. (Attach additional sheets as necessary)** Tweaks in lecture content (additional material on interfacing, embedded software development, new references for ethical and environmental lifecycle considerations), additional equipment for lab, larger quantities of standard supplies, purchase of a professional software package for maintenance of electronic lab notebooks – e.g. LabTrack (still looking for funds).

Appendix A:

Senior Design Reports

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2012
Advisors	Prof. Meyer and Dr. Johnson
Team Number	1
Project Title	VIPER

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Justin Huffaker	CmpE	Software	May 2012
Ryan Hannah	CmpE	Embedded Design	Dec 2012
Aaron Garrett	EE	Packaging and Hardware	May 2012
Brendon McCool	EE	Embedded Design and Signal Processing	May 2012

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

Project VIPER, or Virtual Imaging Peripheral for Enhanced Reality, is a virtual reality system modeled around the interaction of a beacon unit and handheld screen held by the user. As the user moves the screen's position and orientation relative to the beacon, the user will see a virtual environment modified by the same movements as if they were viewing another world through a small, moveable window. This product is intended for use in fields such as architecture where viewing complex three dimensional models is important, or applications such as a museum where the product can provide a more intuitive and intimate interaction for the users to a virtual model or exhibit. The overarching purpose of this project is to introduce a new way to interact with three dimensional objects that is not bound by two dimensional controls such as buttons or mice, and also to make the experience more intuitive, intimate, and accessible to a wider audience. This is achieved though the process of tracking the position of the unit and displaying the appropriate angle of the object being viewed. The approach used in the project was based on two absolute measurements of position and orientation based on the static location and orientation of the beacon, coupled with three relative orientation measurements based on the dynamic orientation of the hand held unit to estimate the perspective of the environment displayed to the screen. All five measurements were filtered together in software to eliminate error and generate the perspective data for the graphical interface.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

Many of the courses in the ECE curriculum were responsible for preparing our team with the knowledge required to implement this project. Perhaps the most instrumental course in our projects completion is *Microprocessor System Design and Interfacing*. Our project utilized three different microcontrollers and a microprocessor, all of which required multitudes of embedded system design concepts and practices along with the interfacing

required to communicate data between the four modules and their five measurement sensing devices. A few of the sensors required more special attention, namely the ultrasonic based distance measurement and the IR LED angular displacement measurement. Basic filtering and amplifying techniques were used to pass the ultrasonic signal to from the beacon to the hand held unit using techniques based on *Linear Circuit Analysis I and II.* The IR measurement was processed the most, with techniques used from *Digital Signal Processing and Applications* in order to extract, recreate, and filter the image from the camera module. Also instrumental in our completion of our project were *Advanced C Programming*, *Intermediate Microcontroller Programming*, and *Intro to Computer Graphics*.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

In the completion of this project, many new technical knowledge and skills were developed. For the members of this team, this project was their first experience with PCB design and population. Many of the techniques and considerations when creating or designing a PCB were both new knowledge and required knowledge for the project. While the members of this team had varying degrees of experience with microcontrollers and embedded system design, this project was the first experience with embedded C programming for the majority of the team.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The engineering design process was instrumental in the successful completion of this project. After identifying the problems associated with point tracking in three dimensions, we drafted many possible options for achieving the response that we wanted from the project. Specifically, the team identified absolute position and angular displacement measurements as vitally important and devoted time and success criteria to these measurements. After evaluating the project further, it was revealed that the communication protocols for controller to controller specifications would need to be developed as well as filtering processes for the imaging module. After prototyping the system on a breadboard, it was discovered that the project would need little modification to work as planned. The success of the project was verified by testing each of the components individually under normal usage circumstances. Based upon evaluation of the success criteria set at the outset of the project, the team successfully accomplished the objective established for the project.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: The economic concerns of the VIPER team were not overly impactful. Most virtual reality systems used for a practical application are usually very expensive. Our device could easily be sold for around $1000 to $1500 dollars and be much cheaper than other similar systems.

Environmental: The environmental constraints for the VIPER system are not much greater than most electronics. The system would not be anymore detrimental to the environment than a netbook computer or other similar sized electronic devices. The system could easily lessen its impact with smarter component selection.

Ethical: The main ethical issue was mostly involved with making sure that the user was aware of the proper use of the device. It was noted that it should be clearly stated that the project should not be used as a medical device or in a moving vehicle.

Health & Safety: Since moving objects on a screen can cause nausea or eyestrain it was an important issue to make sure that people would not over use the device. Also, user comfort had to be taken into account to make sure that the user would not hurt themselves while using the device.

Social: The VIPER unit was not designed with any social constraints because the device should not cause any social problems.

Political: The VIPER unit was not designed with any political constraints because the device should not cause any political problems.

Sustainability: The device has a few sustainability concerns, mostly involved with power. The device does not have any power management features as such it is not power efficient.

Manufacturability: Manufacturing the VIPER system should be relativity easy but several things would need to be done to bring it up to the point of manufacturing. More user control and a power management system would need to be implemented before a device could be sold.

(f) Description of the multidisciplinary nature of the project.

This project incorporated many different multidisciplinary aspects into the completed package. The computer graphics and GUI represent areas that traditionally correspond with computer science. The power supply design, LED array, ultrasonic array and amplifying circuitry are traditionally electrical engineering areas. The embedded systems design, interfacing, and programming are traditionally computer engineering areas. Only with the synergy afforded by these fields was the completion of this project attainable.

(g) Description of project deliverables and their final status.

This project includes two major deliverables: the handheld LCD unit, and the beacon unit. Both deliverables were built and achieved full functionality. The communication between the two units allows for ultrasonic distance data and IR angular displacement data to be included in the graphical display. The LCD unit includes three more readings that combine to make the LCD unit follow more realistic motions as the user manipulates the LCD screen.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2012
Advisors	Prof. Meyer and Dr. Johnson
Team Number	2
Project Title	Awesillo-Scope

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Bo Yuan	EE	Microcontroller Programming	May 2012
Yimin Xiao	EE	Hardware(EE/ME)	May 2012
Yang Yang	EE	FPGA Programming	May 2012
Jintao Zhang	EE	Communication, Microcontroller Programming	May 2012

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The customer for this project will be engineering students, research faculties, and engineers in industry in the area of Electrical Engineering. The purpose for this project is to create a low cost oscilloscope with additional function: capture input analog signal and replay it back on output channel for testing purpose. The scope is design to be able to sample analog signal between +12V to -12V, at 100Kbits/s sampling rate with 110/220V 50/60Hz input power supply; output waveform and measurement/control instructions should be display on an external VGA device. An analog system is designed to meet the analog sampling requirement. A ST microcontroller is used to sample data, reconstruct, and doing all user interface control. A FPGA development module was used to generate VGA output signal. A computer power supply unit is used to regulate input power to provide usable DC voltage of other parts.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

The microcontroller programming requires previous knowledge with microcontroller and embedded system which was taught in ECE362. The VGA display unit used VHDL language, which was taught in ECE337. In sampling/reconstruct process, a lot of signal processing knowledge is required; in addition, the measurement requires FFT calculation and many other digital signal processing techniques, which are taught in ECE301 and ECE438. In analog signal processing, knowledge with filters and non-linear circuits are required, which was taught in ECE202 and ECE255. Finally in noise control in the circuit, EMI is a big concern in laying out a PCB, related knowledge was taught in ECE311.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

Through the project, the most important knowledge we acquire is the understanding of microcontroller programming, include embedded C programming, vector table creation, and module utilization. Additionally, we have obtained practical experience with product design; especially hardware selection, PCB design and overall hardware assemble ability. During the debugging process, we also acquired both MCU (Keil) and FPGA (Xilinx) debugging tools to systematically generate programming files and debugging technique.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The AWESILLOSCOPE idea comes from the equipment we have been used in Electrical Engineering laboratories. Since most of our team has learned the method of signal processing, we decide it would be a good idea to make our own oscilloscope that will test our programming and signal processing abilities. We first draft the outline of the product by define the functions, range, and preliminary method of implementation together so we have a first approach of the entire design. After the project was drafted we start to consider the parts function to run the product. It was decided that we will power an external VGA with a FPGA board since it can both reduce the calculation performed on MCU and practice our communication ability. We write embedded C code, VHDL code, and fabricate our PCB during the synthesis phase. All the components were designed to be on one single PCB and placed in one metal box to reduce EM interference. In construction phase, necessary holes were drilled on the box so that necessary function can be performed within it. Testing is the next procedure after the entire product is assembled. Each aroused issue shall be properly handled and resolved. This process may not be the fastest but it ensures that we went through every process of the entire project and let us get experienced with design progress.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: The AWESILLOSCOPE is a low-cost oscilloscope which uses cheap components to get sampling and measuring functions done. Overall it cost less than $200, which is much less than general oscilloscopes have the similar functions (~ $1000 - $ 3000).

Environmental: We manage to reduce our product's environmental impact by choosing RHoS components, so when disposal, the components will not contain hazardous materials. Also recyclable packaging materials were selected for packaging. So the exterior of the product will be separable and recyclable.

Ethical: With highly consideration of safety issue, AWESILLOSCOPE can hardly be used in an unethical way. However, to ensure a safety use for users, this product should be used only by experienced engineers or people who have completely read the user manual. So that AWESILLOSCOPE can produce proper result and minimize the probability of damage the product.

Health & Safety: The major concern on safety issue of AWESILLOSCOPE is that the product will not generate harmful voltage for user on any port or box itself. Additionally the sustainability has also been taking into consideration. The failure rate of any internal component is limited and should be able to survive any user input within +/- 12 Volts regardless of the

Social: The basic idea in social consideration is to simplify the control panel. By implement a multi-level menu, it will be easy for user to interacting with the device. This goal has driven us all the way through our design process.

Political: No significant political concern was considered in this project. Since all the individual sequence and even the whole product has already be patented and expired, it would be merely any concern for us to re-synthesize the parts.

Sustainability: Oscilloscope itself should be a sustainable product. So what we need to do is not keep the product fresh. On the other hand, we need to make the product as sustainable as possible by minimizing the possible failures of internal parts. Additionally, the overload condition from user input should take into consideration since this condition is allowed in actual use.

Manufacturability: In manufacturing process, the internal component and the exterior container should be produced separately consider they are different portion and require extra assemble. However, when put the product in manufacture, the size should be even more compact. And the use of internal components will certainly be updated for a better use experience.

(f) Description of the multidisciplinary nature of the project.

Multiple Electrical Engineering disciplines were implemented in the design of AWESILLOSCOPE. In the drafting and analyze phase, electrical engineering majorly involved, including schematic design, PCB layout, and component placement/ connection. Followed by that, computer engineering was utilized in programming FPGA and MCU with the respect of designed PCB. When in debugging phase, a combination of Electrical Engineering and Computer engineering skills were implemented. We use modelsim™, Xilinx to debug FPGA code; Keil u-Vision to debug MCU code; and use DMM, Oscilloscope to debug the signals on external pins.

(g) Description of project deliverables and their final status.

The final deliverable comes in a metal box with 25cm x 20cm x 8cm. There are three BNC ports in the front, indicates channel 1 input, channel 2 input and DAC channel output, respectively. There are also 4 pushbuttons and 2 RPGs on the front panel that can be used to adjust display value or select user menu. Before use the product, the power supply is on its back, the power toggle button is also on the front panel and clearly marked. . Moreover, there is an USB port on the front panel enable user to plug in their USB drive and read/write data from/into their FLASH drive when in USB read/ write mode. If successfully read data from USB, the DAC channel can output the waveform user stored in the FLASH drive.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2012
Advisors	Prof. Meyer and Dr. Johnson
Team Number	3
Project Title	Eye In The Sky

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Joe Katz	EE	Analog Circuit Design, PCB Layout, Hardware Debugging, Aeronautics	May 2012
Upsham Dawra	CompE	Base station Programming, Software Architecture, Integration	May 2012
Samit Sura	EE	Hardware Design, Embedded Software, Systems Engineering	May 2012
Ashwin Shankar	EE	Embedded Software, Hardware Interfacing and Debugging	May 2012

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The project is a relatively small, low cost aerial drone capable of providing a user with a “virtual cockpit” including live video feed and sensor data. It is also able to take high resolution images of the ground below the plane and store them in non-volatile memory. Additionally, sensor data can be stored to non-volatile memory throughout the flight. The product is ideal for surveillance and non-stealth reconnaissance. For instance, farmers can record images of their crops throughout the growing season without walking through large fields. Search and rescue teams could use one or more planes to cover large areas of difficult terrain without endangering themselves.

The plane has a wingspan of approximately 5 feet, and a weight of approximately 3-4 pounds, making it roughly the size of a large bird. This iteration is only capable of flying for about 10 minutes on a single battery charge.

Once the objectives were specified, components were selected, then a board was designed, built, and programmed. Mounting of the custom electronics into the plane was the final step.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

This project built upon prior coursework in several ways. First and foremost, linear circuit analysis was used in simple incidental estimates such as current-limiting resistor values, voltage feedback networks, and, most significantly, hardware debugging. Another class without which this project would have been insurmountable is ECE362. The knowledge gained from that class in microcontroller interfacing and peripherals was essential. Some information from ECE311 was applied to board layout, namely minimizing current loops and optimizing decoupling capacitor placement. Other topics learned from courses that were applied to this project include programming (ECE264) and semiconductor circuit design (ECE255).

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

This project was a learning experience in several ways. For one, part selection to such a large scale was a new experience for most members of the team. In addition, none of the members of this team had used I2C peripherals before. The motion processing algorithms were also new to all team members.
There were several software tools that were new to the team as well. For example, no one on the team had used ATMEL's AVR design studio for embedded programming before. Eagle design and layout editor was new to all of us as well. While we all had some prior experience with schematic CAD programs, the PCB layout software was entirely new to everyone on the team.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The objectives of the project were chosen based on the need for a UAV that can be used perform functions like aerial photography, weather mapping and land surveying. The UAV was targeted for the consumer market, so the success criteria were based on safety, ease of use and seamless control of the R/C plane. Through analysis of R/C planes available in the market, we came up with the ability to monitor pressure, altitude, temperature, GPS co-ordinates and compass readings. We would also give the plane the ability to capture high resolution pictures and relay video feedback to the ground. Sensor data will also be stored on board an SD card. For ease of control and functionality, the system will be controlled using an Xbox controller. Low-cost and lightweight components need to be used in order to increase affordability and chances of flight respectively. The PCB had to be designed taking into account the limited space available in the payload bay of the aircraft. Once the components were chosen, they had to be carefully packaged into the payload bay in order to maintain the center of mass of the plane. Once the hardware was decided, the communication protocol and the software design on the base station were thought about. The microcontroller would use an XBee wireless module to communicate with the base station. The base station GUI would be built using Visual C. After construction of the PCB, the system was tested on the ground for the success criteria listed above. The system functioned as expected for the criteria and is expected to work in the air during flight.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of most of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: There were a few products in the market which had part of the functionality of Eye In The Sky. The cost of these products formed the basis of the economic constraints. Since the product is targeted towards RC plane hobbyists, making it affordable to that particular market segment was another constraint. In conclusion, it was decided that the total costs of the project should not exceed $1000.

Environmental: Several environmental issues will arise during the manufacturing, use and disposal of the system. These involve the PCB manufacturing process, increasing the lifetime of the lithium-polymer battery, using environmentally friendly parts and disposing the non-biodegradable plane components and the battery. One constraint that was of particular concern was that of choosing RoHS certified products, so as to minimize the proliferation of environmentally harmful chemicals.

Ethical: Several ethical issues regarding the implications of using the UAV also need to be addressed. These include the UAV being used to breach the privacy of unsuspecting people, or someone getting injured because the plane was operated with questionable purpose. Given the high cost of the system and the crash-prone nature of operation, only a person with prior experience in controlling RC planes should operate it.

Health & Safety: The finished product will weigh slightly less than two kilograms, so loss of control could pose a non-lethal safety hazard if the plane were to crash into someone. One more constraint was that all the wires were properly insulated and capable of carrying high currents, given the system running at 11.1V and motor running at few Amperes of current.

Social: Because of the ethical issues of breaching of privacy or the plane being used to intentionally/ unintentionally cause destruction, there is a limited consumer market for the plane which is a social constraint.

Political: Eye In The Sky, if misused, has the potential of causing political tensions. Unmanned surveillance is a controversial topic involving privacy and safety of people.

Sustainability: Eye In The Sky was designed to withstand a limited degree mechanical stress, given that it would be landing at quick speeds or could be crashing due to operator error. So giving extra protection to the sensors and battery was a constraint in packaging.

Manufacturability: Manufacturability constraints would include not having a steady supply of sensors at the time of assembly, which could factor in this project, given the different sensors it requires.

(f) Description of the multidisciplinary nature of the project.

The project is a combination of Electrical and Computer Engineering with a strong intuition of flight mechanics. The PCB design and interfacing circuitry involved heave use of Electrical Engineering knowledge. The embedded system design on board the plane and the base station GUI required knowledge of computer engineering. The packaging of the plane required a strong mechanical intuition as it was important to keep the center of mass of the plane intact.

(g) Description of project deliverables and their final status.

The finished product consists of a fully packaged UAV along with a base station app which is able to connect to the UAV via an Xbee module and can remotely control the UAV successfully via an Xbox 360 controller. All aspects of the PSSCs, including storing sensor data to an SD card, being able to capture a still image remote, transmitting and displaying real-time sensor data on base station and being able to control all components of the UAV as well change the direction of the on-board video camera wirelessly were successfully completed. Some additional features, like being able to switch to the original Spektrum controller as a fail-safe were also added successfully.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2012
Advisors	Prof. Meyer and Dr. Johnson
Team Number	4
Project Title	Drink Master 8000

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Brandon Davis	EE	Industrial Control Design, Software Development	May 2012
Danny Hudepohl	EE	Software Development	May 2012
Ryan Rhodes	CompE	PCB Design, Software Development	May 2012
Stephen Zabrecky	EE	Software Development and Product Marketing	May 2012

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The Drink Master 8000 creates user customizable drinks from powdered concentrate. The customer can select which powders to put into the machine, as well as select the quantities of each concentrate powder to be added to their new drink recipe. The device will pour, mix, and store the drink the customer creates as well as heat or cool it to the customer's specifications.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

The Drink Master incorporates many analog sensors, which required circuit knowledge on how to get the microprocessor to read the correct analog voltage (ECE201). The device also incorporates many high current components, requiring knowledge of amplifying circuits as well as solid-state devices (ECE255/305). The main controller of the device consists of a PIC microprocessor and a Bluetooth module, requiring knowledge of digital circuits and embedded software design (ECE270/362).

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

The Bluetooth connectivity to Mac and Visual Basic applications had to be researched and learned while we were designing the rest of the device. Also, the system uses multiple valves, which required research into valve actuation types and the team had to make sure the valves' pressure ratings would work with the rest of the device. The other mechanical devices such as the mix pump and heating cooling pump had to be chosen carefully as well since specific head pressure and flow rate are needed in order for the device to work

properly. After building the Drink Master 8000, everyone on the team has a better grasp of the specifications and operation of the mechanical components used.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The main objectives which we considered during the initial design phase was the pouring of the powder concentrate, being able to add water on command, mix the concentrate into the water, and be able to move the drink through the device on command. The device would also have to display its status to the user through the use of a LCD or a PC connected through a Bluetooth connection. The analyses consisted of researching valves and mix pumps so that we could do the mixing, and move the water and drink through the device. Various microprocessors had to be analyzed in order to make sure we could connect all of the sensors and peripherals in the simplest way possible. We then took all the individual components required to complete our objectives and worked out how to synthesize them into one package. During this process we had to work out the placement of the mix and holding tanks in order for gravity feed operation. The construction of the device was accomplished in relatively short order due to the incorporation of t-slot aluminum for the main frame. The mix tank, holding tank and heating and cooling subassembly were then added to the frame with support from cut pieces of acrylic. The electronics were then placed into their enclosure and added to the frame as well. The testing took a long time since there are many moving parts, which need to operate in proper order for the drink to be made properly. After the device successfully created a drink from a specified recipe, the device was evaluated on ease of use and the quality of the drink created.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: The device needed to work and operate as expected, though not be so expensive that no person could afford it. With this in mind, the valves chosen for the device were made from a plastic material, which is less expensive than brass or stainless steel. Also, by having a small LCD and more status details being readout on a user-supplied computer, the overall cost of the device was reduced as well.

Environmental: The Drink Master has the ability to clean itself, meaning that some potable water will be wasted when cleaning the tanks or the lines in which the drink flows through. Using fairly small inner-diameter tubing reduced the amount of wasted water. Unfortunately, the smaller tubing does mean that it will take longer to move the drink from the mix tank to the holding tank.

Ethical: The device had very few ethical requirements to fulfill since making a drink from concentrate is a very common task. In order to protect the user of the product, the device uses FDA approved plastics and sealants, this way the user won't get ill from continuous use.

Health & Safety: With all components coming in contact with the product the user will consume, the only other health and safety constraint has to do with the heating and cooling system. The drink is not be allowed to exceed 105℉, this way it is not possible for the user to burn themselves if the drink gets spilled.

Sustainability: Since many components are user serviceable, broken parts can be easily and cheaply repaired, so the impact on the landfill is reduced. Unfortunately, the power consumption of the heating and cooling system is fairly high, so the valves were selected with power consumption in mind.

Manufacturability: The device can be assembled and disassembled easily due to the t-slot aluminum construction. Though, if the device were to be produced on a larger scale, a welded aluminum frame would be used. The mix tank, holding tank, and heating/cooling system were each designed to be fabricated individually, then dropped into the main frame. This reduces the complexity of fabrication by breaking the device into smaller sub-assemblies.

(f) Description of the multidisciplinary nature of the project.

The Drink Master 8000 uses many mechanical components, as well as electronic. This device is a good example of the relationship between electrical and computer engineers and mechanical engineers. The control system of the device is based on software connected through a Bluetooth protocol, which required a good deal of experience in the area of computer science and software engineering.

(g) Description of project deliverables and their final status.

The Drink Master currently makes drink recipes from concentrate whenever a user creates a new recipe from either the Mac or Windows control system. The heating and cooling system is also fully operational and will maintain a set tank temperature plus or minus a few degrees in either direction. The self-cleaning of tanks still needs to be worked on, though only involves software, since all the valves and hardware are already built into the system.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2012
Advisors	Prof. Meyer and Dr. Johnson
Team Number	5
Project Title	BOAR (Big Ol' Animal Roaster)

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Josh Schortgen	BSEE	Mechanics, Analog	August 2012
Jonathan Mulvaine	BSEE	Software, Imbedded	December 2012
Phillip Byers	BSEE	Analog, Circuit design	December 2012
Mike Broski	BSEE	Software, Imbedded	May 2012

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The BOAR is an automated whole hog roaster designed to use microcontroller interfacing in such a way that the user is free to do other things while the electronics monitor the cooking process. Utilization of this microcontroller is seen through automated temperature sensing, push button start, alert capabilities to errors in the process, and wireless communication to an informant that the user keeps on his or her person during the process. This device was designed for a specific clientele with minimal experience using electronics. With this in mind, ease of use was a main focus. Two push buttons, and a rotary pulse generator make up the base station and two push buttons are used on the informant. In order that this machine fulfills its purpose, it must not only cook a whole hog, but do so in a way that relinquishes much of the burden the cook would face otherwise. The whole process will take roughly ten hours which would greatly increase the amount of attention needed by the cook if not monitored automatically. The specifications that make this possible have much to do with keeping the user informed without the need for them to physically be present. The BOAR must be able to detect flame so as to avoid liquid propane to be freely expelled. It must also be able to electronically adjust gas flow which would allow for much more accuracy in defining a correct cooking temperature. To insure that the tank is operating at a commanded temperature, it must be able to track how hot it gets inside. The reason for this is to prevent the need for the lid to be opened which would drastically increase the cook time and decrease efficiency. All of this monitoring must be relayed to the user via the wireless informant so that they may indeed be more productive in other endeavors. Without this feature, the user would still need to be within constant proximity of the BOAR to insure proper cooking. A specific plan of action was developed to accomplish all these goals. To detect flame, a thermocouple was used similar to one used in water heaters. The change in voltage observed from the device is directly related to the temperature at which it is held at. The use of optical sensing was considered, but not enforced because sunlight reflecting off the side of the tank could potentially give a false reading. To electronically control gas flow, a ball valve was used that rotated in different directions depending on the assertion of two signals. If both signals are low, the valve does not move. If one is high and the other

low, it rotates one direction. Inversion of the two signals sends the valve in the opposite direction. Internal relays shut off the valve when it is fully opened or closed. This is beneficial because software can assert a given signal for a predetermined time to guarantee that the valve is fully opened or fully closed. These two points can then be used as a base value from which the user can deviate to find desired flow rates. The temperature is tracked using three resistive thermal devices that varied in resistance according to the heat. These RTD's remain inside the tank throughout the cooking process and can therefore relay constant updates. As mentioned above, constant temperature sensing allows the lid to stay closed which in turn increases cooking efficiency. The wireless device uses a XBEE device with a communication distance of roughly three hundred feet line of sight. At set intervals, the wireless device on the remote does a range check to insure that the user is still within reach of alerts should something happen. Upon request the user can get updated information about the temperatures and elapsed time so far. The only forced alert the user will be interrupted for is an error on the end of the cooker. Software has been established such that when a error occurs, such as a fire outage, the cooker automatically shuts off the gas flow and relays the information to the user.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

Freescale microcontrollers have been used in microprocessor system design and interfacing in the past and that knowledge has assisted in the development of peripheral usage. Feedback systems were used intensively in the op amp circuits to boost the circuit used in conjunction with the thermocouple. Electro magnetic interference was experienced and overcome with knowledge in electronic and magnetic fields. The power supplies used in this project reflected and built upon knowledge gained through classes in power systems and AC rectification.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

Wireless interfacing was a new field to attack. PCB design and development were new areas to the group and became a very beneficial experience. Writing to flash opened up a new area in software and imbedded.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

Establishment of objectives included defining project specific success criteria and the initial means by which these goals would be met. Upon analysis, some adjustments had to be made to insure a cooperative nature between the different goals established in the first design process. The establishment of the systems analyzed in an earlier process brought great weight to the robustness of the schematics and layouts. To prevent hold ups in later processes, great care had to be taken so construction could be initiated with confidence. Once the layouts were complete to satisfaction, construction began. By following the plans established in the synthesis, construction would have theoretically been very straight forward. One major benefit of the engineering process as it deals with construction was the population of the base station PCB. By beginning in the middle and working outward from there, soldering small components was much easier than had it been done a different way.

In testing, it was seen that not every component acted exactly as planned. The tests provided very useful information in fixing minor errors as well as those that needed major modifications. It also showed how similarly the actual product acted compared to the design on paper. Upon evaluation, many things came to light. One in particular was the idea that over-designing is not always a bad thing. Since components rarely work ideally, it is important to compensate. A perfect example is seen in the power supply. By over-designing it, problems of overload were avoided.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: The BOAR has assets in its design that benefit it form an economic standpoint. One of which is the overall cost. This roaster has been compared to different roasters of its caliber and is less expensive even though it contains electronics not included in similar products. Another is that due to the nature of the BOAR, users have the potential to multitask during the cooking process which will result in more efficient planning and preparation of events.

Environmental: The BOAR is a large piece of equipment and therefore consumes a large amount of materials to be manufactured. Fortunately, the BOAR is largely made up of recyclable steel. Not only does this improve the lifespan of the roaster, but also allows for reuse of the materials. This greatly reduces the environmental footprint of the BOAR.

Ethical: The development of the BOAR included robust software systems that used redundant coding to insure that if something goes wrong, the software will take multiple steps to insure user safety. Aside from that, mechanical safeguards have been implemented to decrease the chance of malfunction resulting in user injury.

Health & Safety: Whenever dealing with raw meat, it is important to insure that the food being cooked has been done in such a way so as to avoid food born illness. For this reason, there are multiple temperature sense points rather than a single one. Another safety feature is the mechanical solenoid. If power is lost to the BOAR, the solenoid will default to the closed position. This will greatly reduce the risk of unregulated cooking.

Social: By its very nature, the BOAR is designed to cook for a very large group of people. Social gatherings of a large magnitude can all be fed via one roaster. With such large capacity, this is a very socially based piece of equipment.

Sustainability: The BOAR was designed with long term usage in mind. Electrical components will likely be the first thing to fail on this piece of equipment. The rest of the tank, being largely mechanical, is likely to last much longer by comparison. The components used in the electronics for the BOAR are less expensive than the larger hardware which means less cost to the consumer if a problem arises. Another functionality that benefits sustainability is the fact that when it was designed, the BOAR was built in such a way that it can be altered to work as a mechanical roaster rather than an automated one.

Manufacturability: The BOAR is comprised mainly of steel which can be folded and welded for quick and relatively inexpensive manufacturing.

(f) Description of the multidisciplinary nature of the project.

This product relies heavily on many engineering aspects outside of electrical. Firstly, a mechanical aspect is highly relevant in that the electronics must run the valves and do it correctly. Stresses in thermodynamics, culinary arts and chemistry are present as well to insure an efficiently cooked hog that tastes good and is not put into a roaster that falls apart due to reactions to propane.

(g) Description of project deliverables and their final status.

At this point, the BOAR functions in that it can auto start, regulate temperature and maintain flame presence tracking throughout the cooking process. The use of wireless interfacing and the ability to save to flash have yet to be finalized. The first three things stated above are fully functional and have been amply tested for robustness.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2012
Advisors	Prof. Meyer and Dr. Johnson
Team Number	6
Project Title	GNMS

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Eric Ellett	CompE	Hardware/PCB	May 2012
Larry Price	CompE	Software	May 2012
Dan Grum	CompE	PCB Design/Packaging	May 2012
Jason Rice	CompE	Web	May 2012

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

GNMS is an inexpensive multi-touch enabled table. This product is designed for people who enjoy using tablets and touch phones to relax and play games.The purpose of this project was to determine whether a large, inexpensive touch table using frustrated total internal reflection (FTIR) technology was a viable alternative to more expensive technologies such as resistive touch, capacitive touch, or other proprietary touch interfaces. The most important aspect of this product was the screen, which was designed to be 32”x24”. The entire product is a 40”x32”x40” wooden box weighing approximately 68 kg. The aspect ratio of the screen is 4:3, with a resolution of 1280x960 pixels. The touch was implemented using FTIR by arranging an array of infrared (IR) light-emitting diodes (LED) around the screen, which was composed of a thick piece of plastic and a thin piece of tracing paper. A web camera was modified to filter out all visible light and only collect IR data and positioned inside the package to face the bottom of the screen. This machine was controlled by a microcontroller unit and an Intel Atom motherboard. The microcontroller’s primary jobs were to monitor internal system temperature and control the projector. The motherboard ran a small Linux distribution, and on top of that the team wrote a custom top-level operating system and several custom applications. In addition to the custom applications, open source software was used to interface with the IR camera and interpret the IR data.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

Early ECE digital design coursework was some of the most relevant for this project. Courses such as ECE270,362 taught us how to use integrated circuits (IC) and how to use online datasheets to our advantage. At the very base was the knowledge of simple circuitry in the earliest ECE courses. For software, the simple C programming courses such as 264 and 368 provided a base which was used in the programming of the microcontroller and the applications. Courses such as ECE462 provided a deeper understanding of object-oriented

programming, which allowed the programming of applications and the top-level operating system. The ECE362 design project taught us how to work effectively as a design team.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

The primary new skill that had to be acquired in order to be successful in our project was printed circuit board design. We had no prior experience in this area before coming into senior design. Another skill worth mentioning was advanced soldering techniques. These higher level techniques were required to solder the more challenging things on our printed circuit board such 603 capacitors.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

Before the beginning of this semester, the group met to brainstorm several ideas for the design. We filtered out the designs that were out of scope and decided on a workable design. During the first weeks of the semester, we came up with our project-specific success criteria (PSSC). With each PSSC, we had to consider time constraints and the constraints of our electronics. We chose several PSSC that would imply that our project was generally working as expected, and several that were more specific to the peripherals. Before all components came available, much testing was performed on individual pieces of the project. We began with simple microcontroller tests, and slowly tested each peripheral as we discovered how it worked. We designed the package in a computer-aided design (CAD) program, and the box was constructed from wood in a workshop. The printed circuit board (PCB) was created in a factory and the parts were soldered to it in the lab. The PCB was tested in-lab with electronic probes and a development tool which allowed for on-chip debugging. For the motherboard portion, we performed human testing by allowing our fellow students to use the applications.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: This was our primary motivation behind the entire project. We wanted to provide a multi-touch table top surface at a fraction of the cost of the comparable competitor surfaces. We focused on using parts that weren’t necessarily top of the line, but rather cheap and sufficient enough to do the needed function. This focus persisted to our software selection as well. We went with all open source and free software which saved us an insurmountable amount of money in terms of licensing.

Environmental: When the electrical components in our project were made, water would have been wasted and hazardous chemicals would have been created. There is currently no power-saving mode included in the product, however one could be implemented to save energy.

Health & Safety: Our product is inherently safe in normal operation due to the fact that it does not require users to exert too much effort in order to operate. There is a slim chance however, that if certain parts of our product were to fail our cooling fans would no longer work thus leading to a catastrophic overheating of our product. Such an overheating would limit the product’s lifetime as well as being a potential hazard to the user. This can be mitigated further in future product redesigns by making the PCB fail safe so that if it fails the

fans will still turn on or by making the product shut down if proper cooling is not applied. Another safety/health concern is possible damage to the user due to improper carrying of the device. The product weighs in excess of 150lbs and thus if it is not carried correctly it has the potential to cause back pain and injury. We have mitigated this by adding caster wheels on the bottom which allow the product to be easily rolled from room to room but there may be some instances where the user will need to carry the product up and down stairs. To mitigate user injury proper carrying instructions would be included in the manual.

Social: This was a secondary motivation of our project. There are many multi-touch devices in the market today such as tablets and smart phones. Unfortunately, most of these devices are used in solitary and we wanted to create a multi-touch device that would be more suitable in social situations. That is why we went with a larger 32"x24" screen that is situated in a table. This creates an inviting environment for multiple people to gather around and interact with the device simultaneously. To build onto this social factor, we tailored most of our games to be for more than one user.

Sustainability: We had sustainability in mind when we designed our product. The casing is made of wood, a renewable resource that can be ethically harvested on tree farms. We tried to limit the size and complexity of our PCB and electrical components to drop our environmental impact. We were able to limit our power consumption down to 269.12W which leads to a very energy efficient means of providing entertainment.

Manufacturability: We set out with the idea to make our design as modular and open as possible. We wanted the user to be able to get inside and customize their own box as they see fit. That is why we used off the shelf parts for the majority of our components within the box. Thus the manufacturability increases because the needed components are highly variable and are not restricted to a single set. Also, due to the primitive structure of our device, it would be a trivial task for any woodworker or robot to build the entire structure of our device in a short amount of time.

(f) Description of the multidisciplinary nature of the project.

The project incorporated a wide range of disciplines including woodwork to simple direct media layer programming. The primary package required us to do a considerable amount of woodwork to create a sturdy yet light weight table. We also had to utilize our circuit analysis skills to create the driver circuits for the fans and the controller led. Both embedded and higher level software skills were needed to program the microcontroller as well as receive serial information to our motherboard through a python program. Finally, we needed to utilize object oriented programming to create the multiple simple direct media layer games as well as the dashboard software.

(g) Description of project deliverables and their final status.

The final deliverable of our project was a fully functioning, interactive multi-touch table. This table included all of the necessary components and software to be a complete stand-alone project. The table was hand crafted and comes with a nice wooden finish with the necessary mounting pieces built into the wood itself. The packaging has automatic temperature control to prevent the components from overheating. Other than positioning the projector and the IR camera, all of the other functions that a user may need to adjust the image is completely controllable from outside of the box. The software consists of multiple games as well as well as some utilities for calibration and custom games.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2012
Advisors	Prof. Meyer and Dr. Johnson
Team Number	7
Project Title	Swish Sleeve

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Sriharsh Achukola	CmpEngr	PCB design & Micro-controller programming/interfacing	May 2012
Stephen MacNeil	CmpEngr	Graphics & Power Management	May 2012
Augustus Hong	CmpEngr	Wireless Communication, Population of PCB	May 2012
Michael Kobit	CmpEngr	Kalman Filter & Software Architecture for Micro-controller	May 2012

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The swish sleeve is a wearable computing device designed to track motion using inertial motion capture. A user's basketball shot can be recreated on the computer without the typical problems of occlusion inherent in optical motion capture. The Swish Sleeve could be used for other sports and further improved beyond the scope of this class to an entire suit which monitors athletes' performance in sports. The customer base in mind are professional athletes whose career is dependent on their performance. This product will allow these customers to monitor their motions and work to fix faults so that their overall performance is maintained or improved. The light-weight mobility of this product allows the user to wear this even during a match and can generate a simulation. This readily available information can drastically improve the performance of an athlete and be beneficial for the team because the coach can make crucial decisions based on the performance of each athlete on the court. The three IMU modules that capture motion are carefully placed on each joint, such as the elbow, wrist and shoulder. The data of relative change in direction is then relayed to the microcontroller, located on the waist kit, where it is filtered using the Kalman Filter. The Kalman Filter uses sensor fusion algorithms and prevents sensor drift to compute the relative location of the arm based on displacement of angle and acceleration. This filtered data is then wirelessly transmitted as a data packet to the base station, an Atom board, that creates a simulation via OpenGL. This approach allows for a real-time capture of motion in 3-D space and effective simulation without any issues that similar products with optical sensors have.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

The Swish Sleeve project consisted of various functionalities such as wireless transmission, microcontroller programming, interrupts/timer functionality, filtering algorithms, animations, etc. The previous ECE courses really played an important role to building the foundation for the implemented functionalities. ECE 362 taught the basics on appropriate Microcontroller programming and how specific modules such as the Timer and UART/SPI work. We used the Timer module in controlling the wireless transmission rate and data extraction from IMU; meanwhile, the UART/SPI was implemented to allow for wireless communication between the Xbee modules. Also, in ECE337 we learned about how UART works and how to read data packets. That knowledge helped us to formulate a way to create an effective data packet to be sent wirelessly from microcontroller to the base station.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

Although we relied on prior knowledge for constructing our product, there was quite a lot of technical knowledge that we had to acquire. We had to learn the I2C protocol, how to effectively implement buck regulator circuitry to regulate voltage from 3.7V to approximately 3.3V, XBee implementation, interpretation of sensor data to demonstrate motion and simulation using OpenGL. The I2C protocol relies on a SDA and SCL line to establish communication between a master, the microcontroller, and the slave, the IMU, is something none of the team members had prior experience in. We had to learn about how I2C works and then devise a way to configure the microcontroller pins to provide a steady clock signal to the IMU via SCL pin and have a bi-directional data bus transmit and receive bytes over the SDA pin. Furthermore, the buck regulator circuit was another component we had to learn because we had to determine the appropriate components required to provide a regulated voltage of 3.3V from a battery source that outputs 3.7V. The most complex part of our product was the ability to interpret sensor data that was provided from both gyro and accelerometer and then run the data through a Kalman filter. The Kalman Filter outputs quaternion points. These were then transmitted to the Atom board where they were converted to Euler angles which were used to dshow 3D motion. This whole process required learning a lot of math algorithms, especially topics such as matrice transformations and translations, Euler Identities, Kalman filtering, etc.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The project had the time duration of a semester and began with determining with the relative direction and goals that we wanted our prototype to achieve. The PSSCs we derived can be considered as the establishment of objectives and criteria stage of our design process. The criteria for our product were: an ability to capture rotational and translational motion for each joint, an ability to coordinate movement between each joint so that the motion of an arm can be recreated, an ability to use OpenGL on an atom board to render the motion captured by the sensors and the ability to Kalman Filter the sensor results so that the variances and noise are ignored. The analysis of our project consisted of creating a block diagram to determine what sort of components we need to successfully build the product. We determined in the analysis of the design process that we will use

gyroscopes and accelerometers at the three joints of the arms to relay motion information of each joint to the waist kit which would then filter the sensor data and transmit it to a PC to recreate the motion. We realized that we would require a microcontroller that would be able to handle 3 I2C modules, 1 UART module, an input capture to read data wireless strength of the XBee, and plenty of I/O pins to display data on an LCD. With an athlete's convenience in mind, we were bound to create the system to be weightless and non-hindering to natural movements. In the synthesis part, we finalized the parts and components that we wanted to use and devised the overall dimensions of the packaging for the waist kit and each sensor module. Once we had the components selected, we used Eagle to create a schematic and printed circuit board that would connect all of our components together as well as providing regulated voltage to the components that needed it. After the schematic and overall criteria had been approved by our professors, we proceeded to the construction part of the design process where we started creating and testing each component individually. We also started attaching the components to the PCB and tested whether or not they were behaving appropriately. This is what is considered the testing phase of the engineering design process. We realized that we had selected a faulty microcontroller while conducting our tests. The Microchip microcontrollers from the series we selected all had problems with I2C transmission. After several modifications, we were able to have it work and started to work on evaluating if we had accomplished all of our criteria. We had accomplished 4 out of 5 PSSCs that we had established in the beginning of the semester.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: Similar product in the market ranges from $1500-$2000 but one of our goals of this product was to make it cost effective. We set the goal to develop the project below $600 and thus far we have been on track with that goal. We buy parts that are inexpensive but versatile as well as develop as much material as we can.

Environmental: We try to pick materials that are recyclable when making the packaging for our design. That would reduce environmental effects to minimal.

Ethical: We report data accurately and mark the limitations of the product clearly on the manual.

Health & Safety: We put warning labels on our project so that small children won't touch it in accident. We also have a user manual so that users know how to safely use our product.

Sustainability: Our project has fairly high sustainability, with the battery life being close to 40 hours. Our parts are RoHS certified, and our packaging is recyclable. The batteries can be recharged and reused for a long time. One of the problems we could not get the battery monitor circuitry to work. This is a small problem because the user will not know how much battery life is left and could potentially drain the battery beyond repair. They will have to manually keep track of the battery life and charge it when they believe that the battery is low.

Manufacturability: We choose components that are off the shelf from the market, and thus are project is easily reproducible.

(f) Description of the multidisciplinary nature of the project.

The project involves hardware components as well as software components. The hardware components including making the PCB board, wiring, and packaging our project. The software component includes writing embedded C code in the microcontroller as well as writing OpenGL code on the Atom board.

(g) Description of project deliverables and their final status.

Project deliverables include the packaged waist unit and arm unit. The waist unit which has a microcontroller in it should be able to collect sensor data from the arm unit and transmit them to the base station. The base station should render those data and generate 3D graphics visualizing the motion made by the arm. Thus far all components have been prototyped and are correct. At the time that this report is due, the packaging is 90% complete.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2012
Advisors	Prof. Meyer and Dr. Johnson
Team Number	8
Project Title	Solar Telematics System

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Brian Kelley	CmpE	Software	May 2013
Dan Ehrman	CmpE	Software	May 2012
Craig Lechlitner	EE	Hardware	December 2012
Clayton Dickemann	CmpE	Software	May 2012

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The Solar Telematics System team has designed a solar car's driver interface and telemetry system. The system will be used in Purdue Solar Racing's (PSR) next vehicle, Navitas. It communicates with the rest of the car using PSR's custom Controller Area Network (CAN) protocol that is implemented on all of the microcontrollers in the car. The driver will see car parameters such as speed and efficiency using a 7" color touchscreen display. The STS also contains an integrated GPS module to track the vehicle's location and a wireless telemetry system to save and transmit data to a duplicate STS on the sidelines.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

The knowledge gained in previous ECE classes was essential to being able to complete this project. Throughout the design process, we utilized much of the information gained through classes, such as circuit design, component selection, power consumption, information on resistors, transistors, and diodes. The concepts learned in ECE 270 and 362 were especially helpful in regards to programming our microcontrollers, though higher-level data structures studied C-based courses like ECE 368 were also of great importance.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

Throughout the process of designing and building the display, we gained a wide variety of knowledge regarding both hardware and software design. Although multiple members on the team already had extensive experience with PIC microcontrollers as well as hardware design and layout, certain problematic obstacles provided us with a chance to learn more about the design process. For instance, during the audio amplifier design, trial and error as well as extensive research eventually led to an adequate filter design. And during software

development, communicating with TSC2000, our system's touchscreen controller, required a great deal of debugging SPI and, for one of our members, learning how to use a logic analyzer extensively for the first time. Memory requirements also provided us with the motivation to learn creative techniques to reduce the memory footprint of code, such as accessing the "Extended Data Space" in internal SRAM or breaking up large images into two separate regions of RAM (internal and external) when they wouldn't fit in one location.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The first step upon beginning this project was to establish what we wanted it to do. As three of the team members were part of Purdue Solar Racing, we had clear objectives for this driver display. As the project progressed, these objectives were refined and refocused, but the core of the objectives never changed. By the time we were able to begin testing our project, we again evaluated if we needed to change anything to ensure our design met our objectives. Testing the product exposed a few issues which were alleviated by, for instance, raising up one of two fighting pins on the board or reconfiguring code to conserve memory. In the end, the system was verified to work by temporarily installing it in PSR's existing solar car where it accurately sent and received data over the established CAN network.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: As a display for a solar car with CAN connections, this product has a moderate cost. Building two of the displays helped remind us to try to keep the cost down for each part. We were lucky enough to have Purdue Solar Racing pay for all of the items, as they will be using our device in the future.

Environmental: As part of Purdue Solar Racing, we were concerned about the environmental impact of our display. The touch screen does use hazard chemicals, but if properly disposed of when its lifespan is over, it will not have an hazardous effect. And the small amount of power consumption (less than 3W) is drastically counteracted by the approximately 500W of power received by the vehicle's solar array.

Ethical: It is extremely important that this product performs well in a race situation. If the driver is depending on our device to continue driving, it must function correctly and be unable to communicate with the engine. The driver display is on a separate CAN network then the motor, so it cannot send commands to the motor in any way.

Health & Safety: The health and safety concerns of our device follow along very closely with the ethical ones. Our biggest goal is to ensure no one gets hurt at any time while using our device. Various software alerts were integrated into the system to notify the driver of any pending danger.

Social: As a product for the Purdue Solar Racing team, our biggest social constraint was ensuring the success of the device in a race environment. We did our best to ensure that it would work within this busy area.

Political: This system is specifically designed Purdue Solar Racings new car Navitas. As a green vehicle, the political ramifications of this design are minimal.

Sustainability: As a solar car, the sustainability of our design is very high. Its vast array of solar panels charge the battery such that, given a proper amount of sun, the vehicle could run forever. However, from a materials perspective, the resources used in constructing the LCD, such as Indium tin oxide, are very rare and expensive and thus do put some, albeit not much, pressure on the sustainability of this device.

Manufacturability: Although the STS is highly specialized in its intended use, it is comprised of widely available parts that can are easily found on any major electronics distribution website. The one exception is that the packaging was produced using a 3D printer; however, increased volume of production would likely necessitate a custom mold or similar technique.

(f) Description of the multidisciplinary nature of the project.

As this project required in-depth programming for the microcontrollers and an extensive printed circuit board, this project encompassed all parts of the ECE school. Our display utilizes two different microcontrollers and multiple ports and protocols, such as SPI, UART, and CAN, which required extensive programming from all computer engineers on the team. From a hardware perspective, the team's residing electrical engineer worked to design a custom power supply and audio amplifier/filter.

(g) Description of project deliverables and their final status.

The final deliverables for this project include two displays. One of the displays is suppose to go into the new car Navitas while the other will function as a pit crew display. Should the display in the car get damaged at any time, the pit crew display can be switched in with minimal effort. The final display was successful in all accounts. We were able to demonstrate all 5 PSSCs and have tested the device in the current solar car.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2012
Advisors	Prof. Meyer and Dr. Johnson
Team Number	9
Project Title	Scribacious Rabble

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
William Hess	CmpE	Hardware Development	May 2013
Paul Rosswurm	CmpE	Embedded Software	May 2012
Benjamin Kobin	CmpE	Embedded Software	May 2012
Mitchell Erdbruegger	CmpE	High Level Software	May 2012

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The project that will be discussed is an adaptation of the board game SCRABBLE® that is augmented by way of electronic score keeping. The project will be able to detect when and where a piece is played on the board along with its corresponding letter and point value by means of a resistive matrix. The game board will also control the flow of the game by displaying information to the players via an LCD. This will display information such as current scores, whose turn, and word challenges. The game will also incorporate an electronic dictionary to facilitate a challenge in the event a player believes the last move included an invalid word. Lastly the game will maintain a set of user profiles keeping track of individual statistics (such as win-loss record, longest played word, and average score), as well as make this information available to the users by exposing it on a USB interface connected to a nearby PC. A software program was created to not only view the player statistics but to also review previously played games move by move.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

This project primarily built upon the knowledge and skills acquired in ECE 362, specifically micro-controller development. The project has the ability to read/write from/to an SD card, display information on LCD screens, take input via rotary encoders and push-buttons, detect tiles and communicate with a PC via USB. All of these were completed with the use of a microchip microcontroller (and various other integrated circuits). Classes such as ECE 270 also contributed to the design of this project by teaching basic skills and digital components (such as shift registers which were used extensively in tile sensing). ECE 255 introduced concepts dealing with analog transistors which came in handy when analyzing power circuitry and designing around the low drop-out regulator used in this project.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

This project introduced the concepts of printed circuit boards with a focus on such topics as trace width and spacing, parts placement, parts selection (in terms of mounting ability), EMI considerations, ground and power layout design, and via considerations. This knowledge was then applied by the creation of a PCB to house the majority of the circuit used in this project. The ability to solder, and subsequently debug, the board was obtained through guided trial and error on the created board.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

This project began with a clear definition of what was to be accomplished, in this case a self-scoring SCRABBLE® board with various other features. From here, this project description was broken down into five independent and testable objectives in the form of project specific success criteria (PSSCs). A preliminary analysis was then completed on each of the specific PSSCs to determine what parts would be necessary to accomplish each individual task as well as an analysis of the overall computational requirements (such as memory space, speed, interfaces like SPI or I2C, etc…) that the project would require from a single micro-controller. Based on the aforementioned analysis, a micro-controller was selected along with all other necessary ICs and discrete components. With the aid of the Eagle design tool, a schematic was drawn up to model the circuit necessary to complete the project. This was reviewed and then utilizing the same Eagle tool a PCB was designed and fabricated. Once the PCB was received, the parts were soldered on one at a time in modules (split up based on what their functions was, so all components related to the SD circuitry were soldered on at once, etc…) and thoroughly tested with the use of debugging LEDs and small sample codes written for the microcontroller. Once every module was soldered and tested, the external interfaces (LCDs, push-buttons, rotary encoders) were added and tested. Once the hardware was completed, the software began full development with a focus on completing each PSSC one at a time and thoroughly testing each previously accomplished goal when a new one was completed. This process was repeated until the project was complete.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: An analysis was performed to price the product. A choice of an MSRP of $200 was chosen as practical based current retail offerings and as such the project was designed to meet this estimated price point.

Environmental: An analysis of the effects that manufacturing our product would have on the environment has been performed. There was not a lot that could be done regarding the PCB manufacturing and energy consumption because the product developed was solely a prototype and constrained by the limitations of the project. However, certain considerations such as choice of packaging material, power-saving software, and recycling instructions were explored.

Ethical: The product developed does not include any anticipated safety risks in the general use of the product. The only perceived concern is the inclusion of small pieces that could be swallowed by a young child. This is an issue in many board game and toy products, and an appropriate age group would be advertised on the final product. Aside from this, it was determined that extensive testing would be the best way to ensure the best product possible would be produced.

Health & Safety: A safety analysis in the form of a FMECA chart was completed on the design and all safety critical components were identified. In the case of this project no safety critical components were identified due to the nature of the SCRABBLE®.

Political: A patent and liability analysis was performed to find if the project was infringing on any existing patents. The original plan was to use capacitive sensing for tiles which has indeed been patented. Licensing or a change in tile sensing would be required. In the case of this project, a switch to resistive sensing was made for implementation reason and has not yet been analyzed for patent infringement.

Sustainability: The safety analysis mentioned above also included a reliability report to determine the MTTF of the project. It was determined to be approximately 20 years taking only the most critical sections of the project into account. This was deemed acceptable based on cost.

Manufacturability: Most of the project could be manufactured fairly easily in a factory setting as most of the wood can be cut easily by CNC machine and all electronic parts are readily available from various sources.

(f) Description of the multidisciplinary nature of the project.

This project mainly focused on computer engineering aspects but also included a few mechanical manufacturing aspects. The game logic and tile detection was all done by use of a microcontroller and other electrical components. However, to manufacture the housing for these components the use of woodworking was necessary. This included cutting out panels to house tile trays, an LCD per player, a rotary encoder and a push button for each player as well as a base on which the panels and game board were mounted. This took a great deal of skills obtained outside of the field of electrical and computer engineering.

(g) Description of project deliverables and their final status.

At the end of the project, a PCB was manufactured and populated with all relevant discrete and analog components. It was thoroughly tested and proven to function in accordance with its design. The wood working required for packaging the project was fully completed. The project has the ability to display relevant information about a game to players, such as current scores, and has the ability to facilitate challenges of invalid words. During gameplay, the player profiles of those involved are updated to maintain specific player statistics such as average score and longest played word. The game board can be connected to a nearby computer and, with the aid of developed software, display all player profiles stored on the game board as well as a move-by-move review of every game played. The identity and location of tiles placed on the game board is able to be sensed by a resistive matrix. Each tile has 5 bits in the matrix for identification.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2012
Advisors	Prof. Meyer and Dr. Johnson
Team Number	10
Project Title	Home Enhancement Suite

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Nathan Irvin	EE	Hardware Design/Power Supply	May 2012
Allen Humphreys	ECE	Software/Peripheral Interfacing	May 2012
Daniel Sabo	ECE	Software/Web Server	May 2012
William Bouchonnet	EE	Hardware Design/Interfacing	May 2012

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The Home Enhancement Suite was initially imagined to be a device that could provide a seamless experience for a user, such that when they enter a room in their home or office the lighting and television would automatically adjust to their preferred settings. In addition, if they were entering their home or office from the exterior, the use of RFID would unlock the door and adjust the internal environment to their preferred settings. The intended customer is either a home/apartment owner or a small company with less than 10 employees and individual office spaces. The Suite could save time and also energy by automatically turning off the devices when leaving the room. The basic approach used to create the Suite involved brainstorming ideas that we could incorporate, designing and testing circuits to implement the ideas, designing the PCBs, and testing/debugging the functions on the boards and making the necessary changes for proper operation.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

With ECE, a vast majority of new designs and work has to be researched and learned for each project. Everything is based on the principles and foundation learned, but each individual design/project requires a new circuit and new code. With that being said, we absolutely utilized the basics including how regulators, BJTs, reset pushbuttons, I/O pins of the micro controller, decoupling capacitors and many other parts work. The fundamentals of embedded C are essentially the same as C. So, the programming skills we learned in CS158, ECE264, 368, and 469 were all built upon. In ECE362 we learned how to interface with microcontrollers using standard communication protocols like UART and for this project we implemented those skills in the form of embedded C versus assembly.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

Any time you are faced with a challenge or a trial, it requires you to learn how to properly fix it. When this happens, learning always occurs. We faced many challenges throughout the project. Some major hardware knowledge acquired was the importance of designing the power supply with headroom above the worst case scenario and ensuring the regulated output will have minimal ripple. We also learned how important it is to thoroughly read through all data sheets and application notes. In addition, we learned how difficult it is to make changes to a PCB after it is manufactured and therefore, an ample amount of time should be spent in the design phase to avoid future changes. In terms of software design, no one had any experience in developing microcontroller software in embedded C. Even though it's fundamentally the same, the C libraries provided by the manufacture put a completely different spin on how things could be initialized and what utilities could be used. Implementing Ethernet was challenging for both hardware and software. We had to learn how to use a large embedded C library to implement it.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

After brainstorming the project concept and deciding what features should be included we established Project Specific Success Criteria. These were designed such that they were independent of each other and contributed to the overall functionality of the Suite. Next, we analyzed each criteria and determined what resources would be needed to accomplish each one. We chose the necessary components including the micro-processor, RFID reader, and PLIX. Next we designed the circuitry for the components to function properly and established a power supply to output 12 VDC, 5 VDC, and 3.3 VDC for the various components selected. This is the synthesis of the design process. After this we constructed the various circuits and interfaced them with the microcontroller for testing purposes. We evaluated the functionality of each objective and made corrections as necessary resulting in a completed product that successfully demonstrates three of the previously established Success Criteria.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: Considerations were given to the cost of each part to ensure that the best deal was found on a part by part basis. When there were multiple manufacturers available, the option that included all of the necessary features for the least cost was selected. The power consumption was also of concern and the final design was chosen to optimize the efficiency as much as possible and reduce direct path current where possible.

Environmental: The major environmental concerns for the Home Enhancement Suite are proper manufacturing, disposal, and power consumption. Any harmful pollutant can be properly dealt with during manufacturing and disposal with appropriate care, and that is why both manufacturer selection and a robust recycling program are necessary. The controller itself also contains energy efficient systems and recommends low-energy usage settings to the user.

Ethical: Proper security and safety are the Home Enhancement Suite's main ethical challenges. The controller is extensively tested to work correctly to ensure both the lighting controls and electric lock work properly, preventing any potential harm to the user. Reliable security on the web interface is also added by password protection to prevent malicious attackers from manipulating settings.

Health & Safety: The Home Enhancement Suite poses very little risk to the users. It is powered by a power supply that is similar to that of many other home appliances. The home security control poses a potential risk because a failure can lead to an unsafe environment.

Social: The project allows multiples users to enjoy an autonomous home environment, yet limits it to only one person controlling the room at a time. The product also transitions seamlessly between users as to not disturb the room environment at all.

Political: The project does not violate and government laws and follows all regulations. If the product were to be manufactured, patent issues could arise.

Sustainability: All parts chosen for the project were well tested and have low failure rates. This should allow the Home Enhancement Suite to be utilized for many years without failure of the product. If a component did fail, and the product stopped working, the board could be sent back and refurbished and a new one sent out. This refurbished board could be used to replace boards in the future and limit the amount of waste by the product.

Manufacturability: The prototype is not the ideal final design. The box selected was chosen for the excess room to allow for modifications and easy implementation. In a production setting, a much more compact design with a better layout would be utilized to reduce the size of the PCB and overall box. A final product would ultimately be a simple circuit board with external ports and switches along one side of the PCB and easily secured with mounting screws to the enclosure.

(f) Description of the multidisciplinary nature of the project.

Our project required both electrical and computer engineering, as well as a little mechanical thinking to complete. All members worked together to fully understand the requirements of the project and implement it in the best way possible. For example, the hardware side of the RFID reader was designed using knowledge of BJTs, data lines, and power circuits. The software side of the project then took the data received by the micro from the RFID reader and manipulated it to see if the correct ID was presented, and turn on/off the various peripherals if desired by the user. A small amount of mechanical engineering was required to design the project's packaging in an aesthetically appealing way. The materials were chosen to be easy to work with, and still give a look that is similar to a DVD player or cable router. Without input from both sides of our project team, the project simply would not function as intended.

(g) Description of project deliverables and their final status.

The final product consists of one Main box and one RFID module for placement near a door. The product successfully allows a user to swipe at the main module and their light settings will be loaded and their name will be displayed on the LCD. Due to power concerns with the XBee radio, it has been left off of the main PCB and therefore the RFID module is

rendered “useless”. However, the program was manipulated to demonstrate the functionality of the door lock, using the RFID reader in the main box. The ambient light sensor was also not utilized and the settings must be set directly in the program. Although the embedded web server is operating correctly using a demo board, the ethernet circuit on the main board does not allow for connection to the network and therefore the settings can not be accessed by the micro on the main board. At this point, the Suite is capable of unlocking the door, adjusting the lighting and allowing multiple users to swipe in and have their settings loaded.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2012
Advisors	Prof. Meyer and Dr. Johnson
Team Number	11
Project Title	Rev Geo Multipurpose Puzzle Box

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Dan Chambers	EE	Power	Dec 2012
Jeff King	EE	Hardware	Dec 2012
Josh Marchi	CompE	Software	May 2012
Paul Rosenberger	EE	PCB	Dec 2012

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The RevGeo Multipurpose Puzzle Box is a treasure hunting adventure game. The user will be given a locked box with unknown and known contents inside. The known contents are a GPS, compass, and other electronic control components while the unknown contents are what the user is attempting to discover. An LCD screen is located on the outside of the box that displays directions to the user. The directions will be programmed using a MicroSD card that can be plugged into the PCB inside the lid of the box. The file to be saved to the MicroSD card will be a simple text file in a format containing the number of waypoints, the GPS locations of the waypoints, and text to display to the user to help them find a waypoint. The box will become unlocked when the final waypoint is unlocked and congratulate the user via the LCD screen. It is then that the user will discover what the unknown contents of the box include. During debugging and for added enjoyment, an RFID reader has been implemented to allow access to the box before the waypoint has been reached. This RFID is not intended to be given to the person completing the activity until they have finished the hunt and plan to reuse it. The RevGeo can be used for any occasion, from a casual Saturday afternoon family outing, to a competitive race between two or more teams, to an elaborate wedding proposal, with the ring inside the puzzle box. The possibilities for the RevGeo's use are seemingly endless.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

The RevGeo project required many different types of electrical and computer engineering knowledge both in the design sense as well as in the practical knowledge used for testing and debugging. Before the design was considered, the brainstorming skills of choosing a project were gained and honed in first year engineering classes that taught good design and brainstorming techniques. The initial design phase of the project required skills gained from nearly every course because it required thinking every technical part of the design through in detail including the logic, the analog circuitry, and debugging hardware. Once

the project specific success criteria were set, there was a consistent common knowledge of the project requirements among team members and course staff. The packaging design included skills Paul gained from EPICS courses using Catia, a visual design CAD program and Jeff's prior knowledge from his ECE 362 mini-project were he designed a locking mechanism. The design of the power supplies by Dan used knowledge from courses such as ECE 255 and ECE 433. The microcontroller programming by Josh used skilled acquired from ECE 362 and ECE 495 (Software for Embedded Systems). Simple debugging techniques were gained from lab courses such as ECE 207, ECE 208, ECE 306, and ECE 362. The monochrome images on the LCD screen by Paul were skilled learned from ECE 438.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

Although many skilled were learned while completing this course, some of the most obvious one is the PCB layout design. None of the RevGeo team members had ever been seriously exposed to PCB layout techniques before this course. This skill was acquired by many late nights in the lab and lessons were learned when traces had to be cut and fly wired after the PCB was manufactured, but the experience gained from this will not be regretted. Understanding the issues with the PCB after its manufacture will help make better schematic designers of the team members in the future. In addition, Josh gained a greater understanding of the I^2C serial communication protocol used to communicate with the compass module in the design. He also learned how to calculate distance to target and initial bearing given two pairs of GPS coordinates.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The engineering design process was followed during this course. The original project was started by establishing the objectives and criteria for the PNG Basestation. This idea nearly reached the analysis stage of the design process when it was scrapped and the RevGeo project was chosen. Since this idea was decided about three weeks into the course, the establishment of objectives and criteria had to be done very quickly. Many meetings occurred in a matter of a few days to make all the design objectives clear to all team members. The analysis part of the process was completed with the help of flowcharts and diagrams to walk through the logic of the device and decide on its complete functionality. Overlapping with the analysis part of the process, the synthesis (schematic design) was started by created individual parts of the schematic separately such as the power supplies which were designed by Dan. Jeff took lead of the overall schematic design while Paul led the PCB layout design when the schematic was close to its final revision. At times, the schematic would have to be revised to do analysis which was overlooked previously and the layout would have to be altered accordingly. After the PCB design was complete, the board was sent in to get fabricated. The first item on the construction agenda was to solder and test the power supplies on the PCB. The 3.3V linear regulator gave no issues; however, the 5V boost switching regulator would not work. After days of testing and debugging, the team decided to order a small breakout board for the 5V source. This required the team to backtrack to the synthesis stage because traces on the PCB had to be cut and wires had to be soldered in order to make the breakout board fit. After the power supplies were tested and evaluated, the microcontroller and debugging hardware was soldered and tested. The rest of the components followed soon after until the board was

completely populated. The testing and evaluation phases of the design process started nearly simultaneously with the construction since each part was constructed and tested together. Various issues occurred with the MicroSD card, LCD screen, and servo which controlled the locking mechanism. These issues were debugged and tested promptly and solutions were quickly derived in order to keep the project moving without delay. After construction was complete, more testing was completed on the device to make sure the microcontroller programming worked properly. Some of the testing included taking the box outside to check various functions of the device.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: One economic constraint that is incorporated into the RevGeo design is that the cost of the product has to be comparable to that of similar technology currently on the market. However, there currently is no other game similar to the RevGeo that is available commercially. A number of ways to decrease the price of the device were brainstormed. One cost reduction idea is to remove the breakout boards used for the GPS and compass, and instead have all components soldered directly on the PCB.

Environmental: The environmental effect of the manufacture, normal use, and disposal of the RevGeo were analyzed individually in order to determine the most effective ways to reduce the environmental impact during its lifecycle. Several methods were determined including, but not limited to: advising the user of proper disposal methods after use, reducing the power usage of the device, and choosing components that do not contain hazardous materials.

Ethical: The main ethical constraint of the RevGeo is that it will not damage the valuable items placed inside the box. This constraint required a reliability analysis to be completed earlier in the semester. There are potential ethical constraints for similar devices that would be programmed to deliver secure documents or valuable items instead of acting as a treasure hunting game.

Health & Safety: The packaging of the device ended up making the lid the heaviest part of the box. Thus when the box is opened, it is prone to fall over if the user does not pay attention. If the user is not aware of this, it may cause personal injury to the user. This is something that will be reanalyzed in a second revision of the RevGeo.

Social: The RevGeo game has to be fun and interactive in order for people to want to buy the product. Brainstorming and analysis were done early in the design process to make sure the functionality of the device is not just achievable in the time allotted for this course, but also desirable by the potential customers.

Political: There are no political constraints that were involved in the RevGeo design.

Sustainability: The box used for the skeleton of the RevGeo is highly rated and tested to survive many different environmental conditions. The durable case is one of the items addressed so that the device will last longer and therefore be more sustainable. A number of other items were addressed in the reliability analysis completed on this design.

Manufacturability: There are some temporary fastening methods used so the design would be completed on time. Velcro is used to attach the battery packs; hot glue is used to secure the servo and LCD screen as well as the stand-offs to which the PCB is secured. These are to be adjusted in a second revision of the device to allow for quicker and more efficient manufacturing.

(f) Description of the multidisciplinary nature of the project.

The RevGeo was certainly a multidisciplinary project in the sense that it involved more than just electrical and computer engineering knowledge. There were aspects of the design that required mechanical knowledge and sometimes just plain creativity. The device packaging and the design of the locking mechanism was the most mechanically involved aspect of the design. The box was bought and it was decided to use the inside of the lid to house all of the electronics. Once this was determined, the PCB was designed to fit in the top of the box while allowing for both a battery and a servo to fit. The locking mechanism was designed by Jeff and used a servo attached to a mechanical device which moved a hook horizontally. .

(g) Description of project deliverables and their final status.

The RevGeo Puzzle Box was finished according to the goals the team had set at the start of the semester. The project deliverables include a small sturdy box with an LCD screen and push button on the top and a switch on the back. Inside the lid, there is a locking mechanism controlled by a servo, a li-ion polymer battery and a pack of 4 AA batteries attached by Velcro. Then there is a PCB which has two power supplies, a FT232RL debugging circuit via USB, a PIC24 microcontroller, MicroSD card socket, compass, RFID, and GPS module which is attached to a powerful antenna which sits in the bottom of the box. Along with the box, there will be a user manual that gives troubleshooting advice, setup and game play instructions, and other general device information.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2012
Advisors	Prof. Meyer and Dr. Johnson
Team Number	12
Project Title	Super Tank

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Jason Holmes	CmpE	PCB creation, embedded programming, scripting	May 2012
Matt Wickesberg	CmpE	Android development	May 2012
Matt Guenette	EE	Custom component creation, packaging	May 2012
Michael Piercy	CmpE	Embedded programming, packaging	May 2012

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

Super Tank is a remote controlled tank that is driven over a wireless internet connection. The physical controller for this vehicle can be any Android device loaded with our custom application. Through this app, users can control the movement of the tank, its turret, and its cannon. Super Tank also operates semi-autonomously, utilizing an array of long and short range IR sensors to avoid obstacles and drop offs.

This tank is marketed as a toy while remaining friendly to hardware hackers looking for a development platform. The purpose of this project was to succeed in achieving long range vehicle control through collaboration with the Hong Kong University of Science and Technology. While Super Tank is just a toy, long range and remote control of vehicles has a plethora of applications and continued prototyping is necessary to advance the technology.

The tank itself is approximately 25.5” x 11.25” x 9”, and has a minimum run time of 20-30 minutes with full utilization. It runs off of a 12V drill battery with quick swap capabilities and is driven by 12V DC motors. The PandaBoard was integrated into the project in order to facilitate wireless video streaming and general WIFI communication.

We approached the design of this project from a system level standpoint. There were several design decisions involved with the higher level questions including implementation of WIFI communication, video streaming, and extensible communication protocols.
As these decisions were made, we dove into the specifics of PCB design, component selection, and component installation.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

The courses vital to our success in this project were ECE 362, ECE 270, ECE 462, ECE 264, and the ECE 207 and 208 labs. The labs gave us hands on experience in dealing with most of the discrete components involved in this project including MOSFETS, BJTs, resistors, capacitors, etc. The experience gained in ECE 362 allowed us to initialize and configure all the peripherals used on our microcontroller. Our overall structure involved several timer interrupts as well as the setting of flags for the purpose of signaling other events. This was based largely on the structure of code in the 362 labs as well as Jason's use of timer interrupts in his mini-project. Additionally, both 362 and 270 gave us the ability to properly read component data sheets.

ECE 264 allowed the team to jump right into embedded coding with the knowledge of C programming including pointers, arrays, functions and variable scope. ECE 462, taking by Jason and Matt W., advanced our knowledge in object oriented programming in Java and C++ which gave Matt W. a head start in Android development despite his lack of experience with that specific platform. It also encouraged a more modular code structure which made debugging of the embedded and Android software much more efficient.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

During this course we learned about scope and depth of an engineering project. Specifically, we acquired new technical writing skills, how to document your work accordingly, and how to think about the implications and business potential of our engineering project. This is a major intangible that is lost on most new college grads. We all learned at least the basics of Eagle. Jason learned how to design a fully functional PCB, create custom part footprints, solder QFPs and other IC's effectively, and program in embedded C. Matt W. learned how to develop advanced applications in Android which incorporated multi-touch, networking, and video display. Additionally, Matt W. gained experience on network design, multi-faceted system design, and leading an international software effort. Matt G. learned how to make custom footprints. Michael learned how to initialize an ADC and help in packaging electronics into a tank platform. In addition, the team learned how to create more effective presentations in order to describe project development.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The Super Tank project spawned from the Long Range Vehicle Control concept developed by Dr. Johnson. The basic goals of this project were to create a vehicle that could be controlled from anywhere in the world in collaboration with the Hong Kong University of Science and Technology. From there, the team developed a more specific idea: an internet controlled tank with firing capability providing video feed back to a "virtual controller". With that idea firmly in place, we set our goals and, similarly, our PSSCs. Because the tank was to be controlled over a long range through the internet with latency unavoidable, the tank would need to be semi-autonomous in order to avoid obstacles that may cause damage. Several forms of feedback would be necessary for the driver, possibly at a remote location, to have a feel for the environment and state of the tank. For this reason, we decided to add

battery management, video feed, event feedback to a status text box, and radar feedback. Lastly, for freedom and reasonable operation, commands and feedback would all be wireless.

After a few thorough rounds of analysis and discussion of the operation of our design, we began to test our methods of communication and sensor use on our development board. This very quickly translated into testing the same methods on our PCB. Construction truly came into play when we were finding locations for our sensors so as to keep them accurate and safe. Testing was needed to make sure our autonomous control worked along with the wireless Android controller once all of the packaging was finished. After the completion of our testing, we chose to observe our design from a prospective manufacturer's standpoint and noted what changes we would make to the design before it ever went into a state of production.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: Super Tank did involve some rather expensive component selection as evidence of its $600 price tag. Commercialization of the Super Tank would most assuredly bring down the final cost however. For instance, a professional design team would be able to incorporate the webcam into the PCB design with a wireless module and keep the interior components to a single PCB. Additionally, we would better source our parts and buy in bulk quantities further reducing our cost. With the above in place we could trim the overall cost to ~$100-$150.

Environmental: Due to energy costs associated with the fabrication of the initial tank, electronics fabrication, and power use over the time of the device life, our cost was about 2.5 tons of CO_2 produced. As the design stands, this can only be marginally improved with proper disposal of the device. This is solely due to the inherently high energy costs of fabrication of electronics and Super Tank's lifespan's energy consumption. A better way to make this product more environmentally sound is to make a re-design of the Tank that focuses on two things. (1) Use less electronic components overall (aka remove the PandaBoard) and (2) reduce the average power consumption of the device.

Ethical: As for ethical concerns we constrained our analysis to the residential use case of our project. Simply speaking, we restrict the analysis to focus on Super Tanks as a toy. As a toy, we needed to be conscious of the safety of our intended audience, children. Therefore, we needed to adequately test the safety of the Super Tank's airsoft cannon and moving components. We found that, with proper documentation and the use of PPE (Personal Protection Equipment), Super Tank is remarkably safe. With the assurance of safety in mind, the mitigation of environmental costs, and the lack of political implications we find that Super Tank is a very ethical product.

Health & Safety: As the name implies, Super Tank is a tank. The tank does have the ability to fire air soft pellets and this may be a concern for some parents. This is mitigated by wearing safety glasses when playing with the tank and employing proper adult supervision. The only other danger that the tank could present would be the ability of the tank to run into, over, or off of things. These have also been mitigated by our autonomous nature and IR sensor feedback.

Social: Super Tank is a toy that can certainly encourage healthy social usage from the user. It does so by encouraging users to play with the toy across large distances. The product goes on to allow the user to immerse himself in a foreign local (usually a friend's house). These characteristics allow users to easily foster their social skills.

Political: In our current market, the toy market, we do not create a large amount of impact on the political landscape. In contrast, if someone were to modify our system to be an actual controller of war machines then our project really could impact politics. Being that this is not our intent we could do a few things to stop the later use case from happening. (1) We protect the project with strong IP and (2) We could make sure the robustness of its command and control system is only sufficient for toys.

Sustainability: From our analysis of the reliability of super tank, we find that there are two main components that are likely to fail. These are the micro controller and the motor controllers. Both of these had a higher failure rate due to high junction heats. This can be alleviated with the simple addition of supplemental cooling to the design in these areas.

Manufacturability: The major obstacle in the Super Tank's manufacturability is its economic costs. Moving past that, we found some additional obstacles to manufacture Super Tank. Mainly, our final design would still need some further testing to prove the reliability and safety of the product. We would then need to gain compliance with the FCC as a class B device. If all of those steps were completed we would then sell our design to large scale manufacturers. To finally translate our design into a fully commercialized product the large scale manufacturers would use their expertise to make Super Tank into a reality.

(f) Description of the multidisciplinary nature of the project.

The creation of Super Tank required knowledge in a variety of different subject areas. Its operation is mechanical in nature, using gearboxes in combination with DC motors to control movement. Care had to be taken to use the correct voltages and supply enough current to provide enough torque for off-road operation. The design process also involved embedded programming, PCB fabrication, and higher level Android programming and networking. In this way, the project spanned Computer Engineering from the hardware level all the way up to the most abstracted form of programming.

(g) Description of project deliverables and their final status.

Our project deliverable is a fully functional WIFI controlled tank capable of being controlled from anywhere in the world and the Android controller that goes along with it. The user can control the movement of the tank, movement of the turret, and firing of the airsoft cannon through the Android application. The embedded system in the tank implements obstacle avoidance by gathering distance information from an array of 10 IR sensors and preempts user controls to avoid damage to the tank. A battery fuel gauge system has been implemented that relays percent capacity remaining, average current, and estimated time remaining based on these two metrics back to the controller. A webcam attached to the PandaBoard is the source of video that the Android application pulls from in order to provide the user with a look at their surrounds from the tank as they are operating it. All of these features fulfill our PSSC's.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2012
Advisors	Prof. Meyer and Dr. Johnson
Team Number	13
Project Title	Beethoven's Ear

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Martin Pendergast	CmpE	Hardware/Software Design	Dec 2012
Stephen Edwards	CmpE	Software/Hardware Design	May 2012
Nick Kwolek	EE	Analog Design/FFT Design	May 2012
David Duemler	EE	Analog/Filter Design	May 2012

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The goal of this project was to build a device that could take in live audio data and analyze that data to output a file containing the sheet music for the audio. More specifically the data would be filtered and sampled before being passed to a microprocessor that would perform the frequency analysis using the Fast Fourier Transform (FFT) algorithm to produce the frequency data which could then be interpreted as musical notes to be transcribed onto a SD card. The target customers for this device would be any level (beginner to experienced) musician that is interested in being able to get sheet music for what they play quickly and easily. The device, named Beethoven's Ear, will be able to transcribe the sheet music in the form of a MIDI file onto an SD card for a single instrument over the range of C_4 to C_8 in real-time. Beethoven's Ear will have an LCD and a rotary encoder for the user interface and will receive audio data through a microphone.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

The project is based around an accurate and efficient frequency analysis performed on a microcontroller that will also be communicating with some peripherals (LCD, SD card, rotary encoder, and ADC). Knowledge of how to perform frequency analysis on a continuous waveform using digital devices came from multiple courses involving signal processing at different levels. Implementation of a good analog front end to reduce noise and amplify the signal before it is sampled was also learned in several classes related to circuits and filters. Circuit design labs were invaluable sources of experience when it came to isolating problems and testing the operation of the analog parts. The knowledge and skill to program a microprocessor to run the FFT algorithm and interface with other peripherals was developed in various programming courses. Without prior experience programming a

microprocessor that development time for code would not be manageable for a single semester project.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

Many different technical skills were gained from completing this project. Firstly we learned the proper flow of the design process when designing an embedded device. Along with this came experience with Soldering, Part Selection based on appropriate design criteria, and an ability to properly acquire and use relevant parts information from different sources (such as datasheets). We also learned a lot of general debugging skills when dealing with microcontrollers and embedded programming.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The engineering design process was very important in developing a working product. Beethoven's Ear started as a general objective that our team wanted to accomplish; a device that could take in love audio and output the sheet music for the input. From this objective we established how to implement this using our existing knowledge and the resources available to us. From our existing knowledge a concept of how to implement the device was created which was then analyzed for its viability as a device that could be completed in one semester while also meeting the requirements for the senior design course. The concept was picked apart and discussed until there was a reasonable set of goals and constraints were determined. Some goals and constraints include: real-time performance capability, desired sampling frequency, FFT window length, specifications for the computation power necessary, user interface specifics. With some basic calculations for part requirements parts were selected and a schematic of the parts came together. Once the schematic was satisfactory PCB layouts were created and redone until the layout had been optimized. Once the parts and the PCB board had been collected the board was populated and testing circuits were made to check that each section worked properly. We ran into some issues which forced us to reevaluate our design. Namely, we had to do a redesign on our power circuit and also modify our original FFT code due to memory constraints. The final evaluated product is not necessarily what we had envisioned it, but after revisions in the design process it completed its necessary functionality for the Senior Design requirements.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: The economic constraints were taken into account often when making design decisions. We used price to help select our components (mainly the microcontroller) and also analyzed the cost of similar products to ensure what we had could be manufactured for less and sold for more.

Environmental: The environmental aspects of the project we're taken into account when we we're studying and extrapolating information on the manufacturing of our device. We assessed the impact the manufacturing process, the usage and the disposal of our device and how we could change our design to minimize that impact.

Ethical: Ethical aspects were taken into account throughout the project. We analyzed whether or not the device could be used in any heinous way to somehow capture or steal music (which the device is not capable of). We also made sure we had an ethical testing procedure to ensure we did our due diligence to protect the users of the device.

Health & Safety: We analyzed the safety aspects of the device and went through and listed the failure modes of the device and their corresponding criticalities. We made sure we accounted for any medium-high criticality errors in our design and appropriately minimized the failure time of the device to a reasonable period.

Social: We analyzed the social impact of the device and we took into account how it was going to be used and what its possible uses were both in the first iteration of the design process but also in following iterations where we we're forced to modify or change the device based on issues we ran into.

Political: The political impact of the device was not heavily discussed. We did go through and check for patents and any possible existing infringements either direct or under the doctrine of equivalents. We found that there was no overlap, and we would be able to patent our device assuming we ever wanted to manufacture it.

Sustainability: We discussed sustainability while discussing the environmental impact, we looked for replacement parts that were RoHS compliant, and also looked for different ways to recycle and handle the different components of the project after it was no longer in use.

Manufacturability: We discussed the manufacturability through a lot of the previous aspects mentioned. We discussed the costs (both environmental and economic) of manufacturing as well as what necessary steps we would need to take to release a safe and good working product (health and safety as well as social/ethical impact).

(f) Description of the multidisciplinary nature of the project.
The project was mainly comprised of electrical and computer engineering which accomplished almost everything associated with the physical development of the device. Within the field of electrical engineering the areas of analog circuit design, filtering, and digital signal processing were used. Apart from engineering, there was work done concerning patent law so that we were aware of whether or not the device was impinging on existing patents. Other areas such as environmental and ethical impacts were investigated which can extend beyond what the product development engineers would usually have to investigate.

(g) Description of project deliverables and their final status.

The project in its final state can take sample frequency data from the SD card (as would be produced by an FFT function) and determine the MIDI representation of those notes and then compose the MIDI file in software and store it to the SD card. The analog sampling and the FFT we're not fully functional by project completion and they each had latent errors that prevented them from being completed and completed properly.

Purdue ECE Senior Design Semester Report

Course Number and Title	ECE 477 *Digital Systems Senior Design Project*
Semester / Year	Spring 2012
Advisors	Prof. Meyer and Dr. Johnson
Team Number	14
Project Title	Future Register

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Brian Crone	CmpE	High Level Software (C#, GUI), PCB, Documentation	May 2012
Samuel Oshin	CmpE	Software(micro),Hardware Design and Testing	May 2012
Yonatan Feleke	CmpE	PCB, Software (Android, C#), Packaging	May 2012
Matthew Finn	CmpE	Packaging, Software (Speech Recognition)	May 2012

Project Description: Provide a brief (2-3 page) technical description of the design project, as outlined below:

(a) Summary of the project, including customer, purpose, specifications, and a summary of the approach.

The Future Register is point of sale system designed to implement new technologies in order to provide a faster and more convenient checkout process for both customers and cashiers. The product was designed to be used in environments similar to a fast food restaurant in which the patrons order their food at a counter. Ideally, the customer should be able to walk up to the register, speak his/her order, then both send payment and obtain a receipt with the use of his/her NFC capable cell phone, thus eliminating all paper transactions in the process.

Future Register implements main features include making near field communication (NFC) transactions, using an infrared (IR) sensor to detect customer presence, speech recognition to aid the cashier in order processing, and a C# application designed with the .NET 4.0 framework. The product will use a dsPIC30 microcontroller to interface with the NFC chip, the IR sensor, and a small LCD screen. The other half of the system will be centered around an Intel atom board. The atom board will power the C# application and handle the voice recognition. The application will be displayed on a 22" Planar touch screen. The microcontroller will communicate with the atom board's serial port using UART.

(b) Description of how the project built upon the knowledge and skills acquired in earlier ECE coursework.

From a software perspective, we were able to use skills we obtained in several different ECE courses through our college careers. Brian was able to use object-oriented design skills obtained in ECE 462 in order to develop the class structure used in the C# application. In addition to the OO design, we all also used basic programming and GUI design skills learned in both ECE 364 and ECE 368.

From a hardware perspective, the most significant course that helped in the design process was ECE 362, microprocessor system design. Although we didn't use a microcontroller in the same family as the one used in class, it was still very beneficial to have worked with one and interfaced to different types of components. This class also helped by introducing some basic soldering techniques used.

Finally, from a design perspective, the most beneficial class taken was ECE 337. Although our project did not use any VHDL, the design process used in ECE 337 was very similar to what we went through for this project. This included creating and updating detailed block diagrams, keeping detailed documentation, and allocating work for several different people.

(c) Description of what new technical knowledge and skills, if any, were acquired in doing the project.

Sam gained much experience with the NFC protocol. He gained experience in embedded C while programming the microcontroller. Both he and Yonatan also gained experience with developing in Java and the Android SDK. The Android app was used to test and demonstrate successful NFC transactions. Brian, Yonatan, and Matt all gained valuable experience with C# and the .NET framework that was used in the GUI. Brian and Yonatan both gained significant experience in using Microsoft Blend to create a WPF project.

All team members gained significant experience in PCB design and the use of the Eagle application. This was probably the most significant skill learned from this class.

(d) Description of how the engineering design process was incorporated into the project. Reference must be made to the following fundamental steps of the design process: establishment of objectives and criteria, analysis, synthesis, construction, testing, and evaluation.

The engineering design process was vital for success with this project. Before the semester even started, we had a basic idea of what we wanted to accomplish with our idea. When the semester started, we used our own developed success criteria along with the course success criteria to determine exactly what we wanted to implement. We had to do an extensive amount of research to determine both what parts we could use with our microcontroller and also exactly what microcontroller we needed to be able to handle all of our components, specifically the NFC chip. Once all of our parts were selected, we had to a lot of analysis of the parts and simulate them on a breadboard to determine that they would be compatible with our design. We had to be as certain as possible with our component selection before we finalized our PCB. Even as we finalized our design, we included additional headers to allow for emergency signal addition if it was needed. Once all of this was finalized, we tested each component separately, then slowly started adding in components until the entire system was complete. Once it was determined, that our components could function together, we constructed the final package and again tested the components in their final environment.

(e) Summary of how realistic design constraints were incorporated into the project (consideration of <u>most</u> of the following is required: economic, environmental, ethical, health & safety, social, political, sustainability, and manufacturability constraints).

Economic: The biggest economic constraint was the LCD touch screen. This was by far the most expensive component, but also one of the most important components. The cost to manufacture this prototype ended up being around $500, with the touch screen

accounting for over half of that. This is an acceptable price though since similar products have been found starting at $800.

Environmental: One of our biggest environmental constraints was again the touch screen. Components like these cannot simply be thrown away. For this reason, we chose a Planar touch screen. Planar offers "Environmental Initiatives" for disposing of their products properly. Also, Microchip is a certified green partner, which was also a minor factor in choosing a Microchip microcontroller.

Ethical: Our biggest ethical constraint was that we would be handling credit card information of customers. For this reason, we decided that no payment information would be stored onto the local hard drive before being encrypted. Also, we implemented the option to back up all locally stored data to a database, where it can be safely stored.

Health & Safety: Future Register did not have any significant design constraints with respect to health and safety. The overall function of the product is not in a situation or environment where it can be a danger to users.

Social: One social constraint we incorporated was to not eliminate cashiers from the transaction process. Our original idea was to automate the transaction completely. However, we decided not to due to the potential destruction of jobs this could create. Also, we designed this product with the aim of making the transaction process quicker and more convenient, thus making the overall experience more enjoyable.

Sustainability: There were not many design constraints relating to sustainability. We assumed that the product would be used in a safe environment and for the most part would not undergo much physical stress. We still built a strong enclosure, but no special designs were needed because the product should not be in much danger.

Manufacturability: Two out of the three parts of our product are already professionally manufactured. Therefore, this leaves a pretty low overhead for manufacturability for the Future Register. We designed the enclosure to be relatively small with no abnormal shapes. The internal wiring is also pretty simple, so overall manufacturability is very favorable.

(f) Description of the multidisciplinary nature of the project.

Future Register is an implementation of our skills from electrical, computer, software, and systems engineering. The high level software, GUI, and speech recognition implementation was a result of our software engineering experience. The PCB and digital circuit design were made possible by our experience in computer engineering. The power supply and management were a result of our experience in electrical engineering. Finally, the design to make all of these components function together was due to our experience with systems engineering.

(g) Description of project deliverables and their final status.

The final product comes in three parts. The first two parts are the touch screen and the atom board. These parts were already packaged when they were acquired. The final package is the PCB enclosure, which we customized. The final product has full functionality. The IR sensor in the PCB enclosure will detect the presence of a customer. The microcontroller will signal the atom board via the COM cable that a customer is

present. The customer can then speak his order, and suggested items based on keywords will show up on the user interface on the touch screen. The cashier will finalize the order, and the atom board will signal the microcontroller that it is ready for payment, at which point the microcontroller will prompt the customer via the LCD screen to place the NFC device up to the indicated spot. The microcontroller will receive the NFC packet and send the payment information to the atom, where the application will encrypt and save the information. The microcontroller will then complete the transaction by sending order information as a receipt back to the NFC device. All of the functionalities just discussed were successfully implemented in our project.